THE EFFICACY OF LENTILS AS A PRE-EXERCISE MEAL FOR ATHLETES OF HIGH INTENSITY SOCCER-SPECIFIC INTERMITTENT EXERCISE

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ABSTRACT

This work examined lentils as an optimal and acceptable pre-exercise meal for athletes of high intensity intermittent exercise. Thirteen male athletes participated in 4 simulated soccer trials with a repeated-measures crossover design. Along with a fasted control condition, isocaloric lentil, potato & egg white, or potato meals providing 1.5 g total carbohydrate/kg were consumed 2-h before the trials. Pre-exercise meal sensory acceptability and digestive tolerability were measured throughout testing with fixed-point scales: A sensory test meal analysis and gastrointestinal digestive symptom rating scale. Participant demographics, nutrition knowledge, and psychosocial perceptions towards lentils were assessed with a questionnaire. Distance covered on a 5 x 1 min repeated sprint test (2.5 min rest) at the end of the soccer trial assessed exercise performance. The Borg Scale (0-20) determined ratings of perceived exertion during exercise testing. Barriers toward pulse-based meal consumption negatively correlated with weekly pulse consumption ($r=-0.902$, $p < 0.05$), while a positive correlation existed between beneficial beliefs of pulse-based meal consumption and weekly pulse consumption ($r=0.620$, $p < 0.05$). Participants consumed an average of 79.5 ± 1.8% of each meal. The meals were perceived large in size and cumbersome to ingest by the participants, and no between meal differences were observed ($p>0.05$). The lentil meal was not as appealing in aroma, appearance, or flavour compared to the potato meal, but no different than the potato & egg meal ($p>0.05$). Lentil consumption resulted in a minimal increase in nausea compared to the other conditions (1.0, 0.54, 0.31 and 0.08, for lentil, potato & egg, potato, and control, respectively, $p<0.05$). Initially after consumption, all meals resulted in more bloating and fullness, and less hunger than control ($p<0.05$). Improved overall exercise performance was proportional with greater pre-exercise meal energy ($r = 0.68$, $p < 0.05$) and carbohydrate intake ($r = 0.67$, $p<0.05$). Pre–exercise consumption of the low glycemic index lentil meal, as well as the two high glycemic pre-exercise meals, resulted in improved total sprint distances compared to the fasted control condition ($p<0.05$). The comparative sensory acceptability, digestive tolerability and similar performance outcomes of the lentil meal to the other pre-exercise meals indicates lentils may be a suitable pre-exercise meal for athletes of high intensity intermittent exercise.

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LIST OF ABBREVIATIONS

AMDR – acceptable macronutrient distribution range
bw – body weight (kg)
CHO – carbohydrates
g – gram or grams
g/kg bw or $g \cdot kg\ bw^{-1}$ – grams per kilogram body weight
g/min or $g \cdot min^{-1}$ – grams per minute
GI – glycemic index
GL – glycemic load
HGI – high glycemic index
HIIE – high intensity intermittent exercise
IMTG – intramuscular triglycerides
IOM – Institute of Medicine
$kcal \cdot g^{-1}$ – kilocalories per gram
$km \cdot hr^{-1}$ – kilometers per hour
L – lentil meal
L – lentil meal
LGI – low glycemic index
$mL \cdot kg^{-1} \cdot min^{-1}$ – milliliters per kilogram per minute
$mmol \cdot L^{-1}$ – millimoles per litre
OPS – overall performance score
P – potato meal
P & E – potato & egg meal
pp – post-prandial
RDA – recommended dietary allowance
RPE – rate of perceived exertion
V_{max} – peak treadmill speed
VO_2 – oxygen uptake
VO_{2max} – maximal oxygen uptake
VCO_2 – carbon dioxide output

CHAPTER 1: INTRODUCTION

Research has highlighted the significant contribution of appropriate nutrition to the optimal performance outcomes of athletes. Scientific investigations to identify optimal fuel sources and supplies are increasing exponentially in an attempt to discover ideal nutrition for optimal athletic performance. An athlete's capacity to generate energy for exercise is dependent on both stored energy and the ability to access, mobilize and replenish energy. Although the timing and composition of the fuel that will enable optimal performance outcomes has been comprehensively debated, concrete guidelines have yet to be developed (Coyle, Coggan, Memmert, Lowe, & Walters, 1985; Hargreaves, Hawley, & Jeukendrup, 2004; Horowitz and Coyle, 1993; Montain, Hopper, Coggan, & Coyle, 1991; Rodriguez, DiMarco, & Langley, 2009). Moreover, as the physical demands of athletes change with the type of exercise performed, the type of fuel, specifically the proportion and origin of macronutrients delivered and the hormonal response generated from the fuel, required to maximize performance outcomes should be specific to the frequency, intensity, time and type of exercise. While an abundance of research has investigated the nutritional requirements of endurance athletes, few studies have focused on the nutritional requirements of athletes who compete in events that require high intensity intermittent activity (e.g. soccer, hockey, rugby). High intensity intermittent exercise exhausts available fuel supplies more rapidly than continuous endurance exercise, and also requires different metabolic mechanisms for adequate energy production (Bergstrom, Hermansen, Hultman, & Saltin, 1967; Hawley, Dennis, & Noakes, 1994).

Several studies have investigated the use of low glycemic-index carbohydrate sources as the optimal energy source for the exercising athlete (Burke, Collier, & Hargreaves, 1998a; DeMarco, Sucher, Cisar, & Butterfield, 1999; Febbraio & Stewart, 1996; Febbraio, Kennan, Angus, Campbell, & Garnham, 2000; Kirwan, O'Gorman, & Evans, 1998; Sparks, Selig, & Febbraio, 1998; Thomas, Brotherhood, & Brand, 1991; Thomas, Brotherhood, & Miller, 1994; Wee, Williams, Gray, & Horabin, 1999; Wong, Siu, Lok, Chen, Morris, & Lam, 2008; Wu & Williams, 2006). This research study aims to further investigate this concept by determining the suitability of lentils (a low glycemic index food) as a pre-exercise fuel for athletes performing high intensity intermittent exercise (HIIE) by examining the acceptability of lentils to participants in a treadmill-based simulated soccer trial. The slow digesting, long lasting carbohydrate and abundant protein content of lentils may provide an optimal nutrient composition that can maximize energy stores, and thereby improve an athlete's access to and ability to replenish energy. This could lead to ideal exercise performance outcomes.

CHAPTER 2: LITERATURE REVIEW

2.1. Exercise Nutrition

Daily and pre-exercise energy and carbohydrate intake patterns can be the most influential factors that affect an athlete's optimal performance in training or competition. The majority of exercise nutrition research has highlighted the importance of carbohydrate storage, utilization and replenishment for optimal steady-state exercise (Sherman, Peden, & Wright, 1991; Wright, Sherman, & Dernbach, 1991); whereby, endurance performance is optimized when athletes begin exercise with saturated muscle and liver glycogen stores (Hargreaves, 2001; Hargreaves et al., 2004; Sherman et al., 1991; Thomas et al., 1991). In contrast, very little research has been carried out related to specific nutrition capable of optimizing the internal metabolic environment for maximal performance of high-intensity intermittent exercise; although preliminary studies have found that prolonging the depletion and exhaustion of endogenous carbohydrate stores may be the dependent variable for optimal performance in this type of exercise (van Loon, Greenhaff, Constnatin-Teodosiu, Saris, & Wagenmakers, 2001).

According to Dietitians of Canada's specific athlete recommendations (DOC, 2010), athletes should consume the same foods as non-athletes, but in slightly larger quantities and more frequently to meet the increased energy expenditure associated with physical activity. Sufficient energy and macronutrient intake based upon an athlete's caloric expenditure are of utmost importance; as training in an energy deficit can reduce training efficiency, metabolize lean tissue for energy production, reduce bone strength, and increase risk of illness or injury (DOC, 2010). The majority of athletes train and compete in an energy deficit (Berning, 1998;

Brouns, Saris, Beckers, Aldercreutz, van der Vusse, Keizer, Kuipers, Menheere, Wagenmakers, & ten Hoor, 1989a; Brouns, Saris, Stroecken, Beckers, Thijssen, Rhehrer, & ten Hoor, 1989b; Kreider, 1991; Kreider, Wilborn, Taylor, Campbell, Almada, Collins, Cooke, Earnest, Greenwood, Kalman, Kerksick, Kleiner, Leutholtz, Lopez, Lowery, Mendel, Smith, Spano, Wildman, Willoughby, Ziegenfuss, & Antonio, 2010; Leuholtz & Kreider, 2001) and do not consume adequate calories to ensure physiological training adaptations for optimal exercise performance (Kreider, Fry, & O'Toole, 1998). Athletes performing high intensity training daily may expend 50-80 $kcal \cdot kg^{-1} \cdot day^{-1}$ (Kreider, 1991; Kreider et al., 2010; Leuholtz & Kreider, 2001). Athletes with energy requirements at the upper end of the range are encouraged to fulfill energy and macronutrient requirements with 4 to 6 various calorically and nutritionally dense meals and snacks throughout the day, as consumption of the recommended intake can be difficult on a typical three meal eating schedule (Berning, 1998; Brouns et al., 1989a; Brouns et al., 1989b; Kreider, 1991; Leuholtz & Kreider, 2001). Although elite athletes require greater energy intake than those of typical Canadians, the range of intakes for energy sources required for disease risk management and nutrient provision defined as the acceptable macronutrient distribution ranges (AMDR) are similar: For carbohydrates, fats, and protein these are 45%–65%, 20%–35%, and 10%–35% of total energy, respectively (Barr, 2006; DOC, 2010; IOM, 2005; Rodriguez et al., 2009; Zello, 2006).

The most influential macronutrient for athletes striving for optimal exercise performance is carbohydrates, as they are involved in lean tissue generation, maintenance, and repair, as well as in aerobic metabolism (Hargreaves, 2001; Kreider et al., 2010). The general recommendation for training athletes is that they should consume 6-10 grams of available carbohydrate per kilogram per day, or an AMDR of 55-65% carbohydrate to maintain glycogen stores, where available carbohydrate is the proportion of carbohydrate that is digestible, absorbable, and can be effectively used to fuel metabolic pathways (DOC, 2010; Kreider et al., 2010; Rodriguez et al., 2009; Sherman, Brodowicz, Wright, Allen, Simonsen, & Dernbach, 1989). The mechanisms by which dietary carbohydrate intake can influence exercise performance have not fully been elucidated but several have been suggested to ensure sufficient skeletal muscle carbohydrate oxidation during exercise. Mechanisms such as improved maintenance of blood glucose for cognitive functioning, motor unit recruitment and substrate oxidation in muscle toward the end of exercise, and the replenishment of liver and muscle glycogen have been shown to prevent fatigue and enhance performance (Coggan & Coyle, 1991; Kirwan, Cyr-Campbell, Campbell, Scheiber, & Evans, 2001; Nybo, 2003; Sherman et al., 1989; Wright et al., 1991).

Inadequate supply of the two most crucial factors of exercise nutrition, energy and carbohydrate, can limit optimal exercise performance and lead to muscle mass and strength loss (Burke, Wood, Pyne, Telford, & Saunders , 2005; Kreider et al., 2010; Lea, Crawford, & Worsely, 2005). Maintenance and prevention of muscle loss is not only attributed to the provision of the aforementioned factors, but also influenced by protein in an athlete's diet. The International Society of Sports Nutrition, based upon recent findings (Kreider, 1999; Lemon, Tarnopolsky, MacDougall, & Atkinson, 1992; Tarnopolsky, MacDougall, & Atkinson, 1988; Tarnopolsky, 1999), recommends that the exercising individual requires 1.4 to 2.0 grams protein per kilogram body weight to maintain protein balance and meet exercise-associated increased physiological requirements (Hargreaves, 2001; Kreider et al., 2010; Rodriguez et al., 2009). As the average Canadian commonly consumes 1.5–2 times the protein Recommended Dietary Allowance (RDA), which is the defined by the Institute of Medicine (2005) as "the average daily intake level that is sufficient to meet the nutrient requirement of nearly all (97-98%) healthy individuals…", highly active athletes may obtain sufficient protein intake resultant of increased caloric intake (Barr, 2006; IOM, 2004; Statistics Canada, 2009). However, this observation may only apply for athletes of general to moderate exercise intensity, and or smaller athletes of lower weight and or stature (IOM 2005; Kreider et al., 2010; Rodriguez et al., 2009). Elite athletes engaged in high intensity training (2-6 hours day of intense exercise performed 5-6 times per week) may be susceptible to protein malnutrition (Kreider et al., 2010), and resulting muscle wasting and training intolerance (Kreider et al., 1998, Leuholtz & Kreider, 2001). Adequate dietary protein intake from sources before and after exercise improves recovery and gains in lean muscle tissue (Campbell, Kreider, Ziegenfuss, La Bounty, Roberts, Nurke, Landis, Lopez, & Antonia, 2007; Kreider et al., 2010; Tarnopolsky, 1999; Tipton, 2001; Tipton & Witard, 2007).

The fat AMDR for athletes also does not vary from normal population recommendations, as athletes require adequate fat intake to meet the physiological requirements associated with fat-soluble nutrient status, essential oil intake, and several metabolic compounds and processes (Barr, 2006; IOM, 2005; Venkatraman et al., 2000; Zello, 2006) such as fat oxidation, neurological functions for sufficient motor unit recruitment (Nybo, 2003), and hormone maintenance and generation (Dorgan, Judd, Longcope, Brown, Schatzkin, Clevidence, Campbell, Nair, Franz, Kahle, & Taylor, 1996; Hamalainen, Adlercreutz, Puska, & Pietinen, 1983; Reed, Cheng, Simmonds, Richmond, & James, 1987). Athletes also require fat for intramuscular triglyceride (IMTG) aerobic fat oxidation in skeletal muscles during exercise (Brooks et al, 2005; Trenell et al., 2008). Extreme endurance athletes obtain 40-50% of the energy utilized during exercise from IMTG oxidation (Muoio et al., 1994; Rodriguez et al., 2009), while athletes of high intensity intermittent exercise obtain energy from IMTG oxidation only during periods of reduced intensity where VO_{2max} is ≤70% (Dyck et al., 1993; Jeukendrup & Saris, 1998; Odland et al., 1998; Romijin et al., 1995). Consideration of specific training state and goals of an athlete are needed to determine fat intake exactly, although general recommendations or a slight increase should adequately facilitate performance gains and promote health (Kreider et al., 2010; Leuholtz & Kreider, 2001).

Overall health of an athlete can also be improved with adequate dietary fibre. The recommended intake of 14 g fibre per 1000 kcal diet (IOM, 2005), is an Adequate Intake (AI) or the amount needed to meet the average daily intake assumed adequate for nutritional and physiological requirements of a healthy population (Barr, 2006; IOM, 2005). Complex or unrefined carbohydrates contain greater amounts of fibre, which contributes to delayed digestion and absorption (Ellegard & Andersson, 2007; Munro, 2007; Venn & Mann, 2004). Adequate soluble and insoluble fibre intake in normal and athletic dietary regimes has been shown to improve overall and gastrointestinal health; specifically, through mechanisms involved with blood lipid profile improvement, gastrointestinal cancer prevention, and blood glucose management (Anderson & Major, 2001; Bazzano, Thompson, Tee, & Nguyen, 2011; Mathers, 2002; Raben, Jensen, Marchmann, Sandstrom, & Astrup, 1997; Shai, Schwarzfuchs, Henkin, Shahar, Witkow, Greenberg, Golan, Fraser, Bolotin, Vardi, Tangi-Rozental, Zuk-Ramot, Sarusi, Brickner, Schwartz, Sheiner, Marko, Katorza, Thiery, Fiedler, Bluher, Stumvoll, & Stampfer, 2008).

2.2. The Glycemic Index

The glycemic index (GI) of a food classifies it according to its post-prandial glucose response, or the rate at which its carbohydrates enter the blood stream as the food is digested (Jenkins, Wolever, Taylor, Barker, Fielden, Baldwin, Bowling, Newman, Jenkins, & Goff, 1981; Foster-Powell, 2002). The GI of a specific food can be determined by following a standardized laboratory procedure to compare the 2-hour blood glucose response after the ingestion of 50 grams of available carbohydrate from a test food to the blood glucose response after the ingestion of 50 grams of a reference food (Jenkins et al., 1981). The standard reference is typically a glucose drink, although other foods may also be used as a standard (e.g. white bread, glucose syrup) (Foster-Powell et al., 2002). The GI of a test food is calculated as:

$$\text{GI} = \frac{\text{AUC}_{\text{Test Food}}}{\text{AUC}_{\text{Reference Food}}} \times 100 \tag{2.1}$$

where $\text{AUC}_{\text{Test Food}}$ is the area under the two-hour blood glucose concentration versus time curve for the test food and $\text{AUC}_{\text{Reference Food}}$ is the area under the two-hour blood glucose concentration versus time curve for the reference food (see equation 2.1 above). With glucose as the reference, a carbohydrate source can be classified as low GI (<55), moderate GI (55–70), or high GI (>70) (Brand-Miller & Foster-Powell, 1996). Table 2.1 lists the GIs of some common foods; however, the GI of a food can differ based upon factors influencing glucose entry and removal from the blood. Factors influencing entry of glucose into the blood include fibre and fat content, the carbohydrate structure (amylose:amylopectin ratio), the method of preparation, and the degree of processing of a food (Björck, Granfeldt, Liljeberg, Tovar, & Asp, 1994; Foster-Powell et al., 2002; Walton & Rhodes, 1997). A GI is also influenced by factors removing glucose from the blood. Primarily insulin, the rate and amount secreted and its action on tissue; but also the food's protein content, and glucose uptake capacity of affected tissues (Björck et al., 1994; DeFronzo & Ferrannini, 1982; Schenk, Davidson, Zderic, Byerley, & Coyle, 2003). The complex structural characteristics of unrefined carbohydrate sources, such as low GI lentils, prevent expedient action of digestive enzymes and reduce rates of glucose digestion and absorption, unlike refined, high GI, low fibre carbohydrate sources (IOM, 2005; Ranawana et al., 2010; Schenk et al., 2003; Thorne, Thompson, & Jenkins, 1983). In contrast, foods containing reduced amounts of soluble and insoluble fibre tend to have high GIs due to quickly digested carbohydrates and the subsequent prompt transport of sugars into circulation (Mondazzi & Arcelli, 2009; Munro, 2007).

Table 2.1. Glycemic index (GI) values of some common foods.

Food	**GI**
Low GI (<55)	
Apple juice	40
Lentils	30
Chocolate Milk	43
Spaghetti, boiled	38
Banana	52
Moderate GI (55-70)	
Blueberry Muffin	60
Power Bar, chocolate	56
Rice, white, boiled	64
Honey	55
High GI (>70)	
Mashed potato	85
Gatorade	78
Bagel	72
Corn Flakes	81
White bread	73

Foods categorized as low, medium and high GI (using glucose as the reference food). GI values are from Foster-Powell et al., 2002.

2.2.1. The Glycemic Load

The glycemic load (GL = GI × available carbohydrate) is used to quantify the contribution of carbohydrate content and GI of meal components (glycemic effect) on glucose absorption rate (Foster-Powell et al., 2002). Both the quantity and quality (i.e. nature or source) of carbohydrates influence the glycemic response; thus, the GL of a given meal is the product of the available carbohydrate amounts and the GIs of the component foods.

2.2.2. The Glycemic Index and Exercise Performance

Carbohydrate containing foods with a low GI designation are characterized by the slow release of carbohydrates from the digestive system into the circulatory system or the fast removal of glucose from the blood (Schenk et al., 2003). This can result in a reduced insulin response (Jenkins et al., 1981; Wolever & Jenkins, 1986) and creates a hormonal environment conducive to improving adipocyte lipolysis and the oxidation of circulating free-fatty acids for energy production. The consumption of low GI foods, therefore, enables the preservation of endogenous carbohydrate stores (Horowitz, Mora-Rodrigues, Byerley, & Coyle, 1997; Montain et al., 1991; Wu, Nicholas, Williams, Took, & Hardy, 2003). Contrarily, high GI foods can cause a rapid and prolonged rise in blood sugar, which produces a high insulin response that may subsequently reduce the proportion of energy generated from fat oxidation during exercise (Costill, Coyle, Dalsky, Evans, Fink, & Hoopes, 1977; Jenkins et al., 1981; Kirwan et al., 2001; Lambert, Hawley, Goedecke, Noakes, & Dennis, 1997; Siddosis et al., 1996; Wolever & Jenkins, 1986). The post-prandial hormonal environment from a high GI pre-exercise meal may therefore negatively affect performance; whereby, glycogen is more quickly depleted. Pre-exercise meals with a greater GL result in faster release of carbohydrates into the circulation and greater insulinogenic properties which may impede exercise performance via manipulations on optimal substrate oxidation during exercise (Mondazzi & Arcelli, 2009). Reduced glycogen levels can limit optimal performance later in exercise, and especially in high intensity intermittent exercise (Hargreaves, Costill, Fink, King, & Fielding, 1987; Hargreaves & Briggs, 1988; Hargreaves, 2001; Horowitz & Klein, 2000; Kirwan et al., 1998; Kirwan et al., 2001). The identification of this metabolic situation has led to controversy in the ability of high GI foods to result in optimal exercise performance when consumed pre-exercise, and has resulted in investigations of low GI, high protein pre-exercise meals for the improvement of exercise performance (Burke, 1998a; DeMarco et al., 1999; Kirwan et al., 2001; Thomas et al., 1991). When compared to high glycemic response meals, low glycemic response pre-exercise meals decrease energy demand from glycogen and increase fatty acid oxidation during exercise (Burke, Cassem, Hawley, & Noakes, 1998b; Chryssanthopoulos, Williams, Nowitz, & Bogdanis, 2004; DeMarco et al., 1999; Febbraio et al., 2000; Guezennec, Satabin, Duforez, Koziet, & Antoine, 1993; Stevenson, Williams, Mash, Phillips, & Nute, 2006; Thomas et al., 1994; Thomas et al., 1991; Wee et al., 1999; Wee, Williams, Tsintzas, & Boobis, 2005; Wu & Williams, 2006). This may be conducive to improved performance in the latter portions of an exercise bout (De Bock et al, 2007). Typical high glycemic load pre-exercise meals, which provide energy and carbohydrate quickly and rapidly increase blood insulin concentrations include mashed potatoes, white bread and preserves, dried fruit (raisins),breakfast cereals with added sugar, carbohydrate beverages, gel packs, supplements and dextrose powder (Burke 1998a, 1998b, Hargreaves et al., 2004, Jeukendrup & Wallis, 2005). Some possible low glycemic load pre-exercise choices include whole grains (oatmeal, quinoa, wheat berries, pearled barely, and brown rice), nuts and fruits, dairy products (yogurt, milk or cheese), pasta, whole grain bread and nut butter or legume purees (DOC, 2010; Febbraio et al., 1996; Thomas et al., 1991, 1994; Wee et al., 1999).

2.3. Nutritional and Metabolic Requirements for Optimal Performance

2.3.1. Metabolic Requirements for Optimal Performance

An abundance of research exists investigating the optimal pre-exercise meal for athletes engaging in endurance exercise (Achten & Jeukendrup, 2003; Burke, 1998b; Chryssanthopoulos, Williams, Nowitz, Kotsiopoulou, & Vleck, 2002; DeMarco et al., 1999; Erith, Williams, Stevenson, Chamberland, Crews, & Rushbury, 2006; Febbraio & Stewart, 1996; Febbraio et al., 2000; Gleeson, 2005; Hargreaves, 2001; Hargreaves et al., 1987; Horowitz & Coyle, 1993; Ivy, Res, Sprague, & Widzer, 2003; Romano-Ely, Todd, Saunders, & Laurent, 2006; Sherman, 1991; Sparks et al., 1998; Wee et al., 2005; Wee et al., 1999). However, little research has focused on high intensity intermittent exercise (Bonen, Malcolm, Kilgour, McIntiyre, & Belcastrol, 1981; Little, Chilibeck, Ciona, Forbes, Rees, Vandenberg, & Zello, 2010; Yaspelkis, Patterson, Anderla, Ding, & Ivy, 1993). This type of exercise is composed of changes in direction, intensity, and accelerating and decelerating to various speeds ranging from walking to sprinting (MacDougall, Ward, & Sutton, 1977; Saltin, 1973), and is practiced in team sports such as soccer, lacrosse, basketball, hockey, rugby and football. While steady-state endurance exercise is fueled by a consistent proportion of endogenous fat and carbohydrate stores, high-intensity intermittent exercise utilizes various metabolic aerobic and anaerobic pathways to provide adequate energy (Jeukendrup & Gleeson, 2004; Kreisman, Ah Mew, Arsenault, Nessim, Halter, Vranic, & Marliss, 2000; Kreisman, Ah Mew, Arsenault, Nessim, Halter, Vranic, & Marliss, 2001; Marliss & Vranic, 2002). During segments of variable intensity intermittent exercise similar to sub-maximal (<70% VO_{2max}) steady-state endurance exercise, adequate energy is produced from aerobic free fatty acid oxidation in a lengthy process that does not produce energy at a rate required for segments of higher intensity (Bangsbo, Mohr, & Krustrup, 2006; Kirkendall, 2004; Nicholas, Tsintzas, Boobis, & Williams, 1999; Saltin, 1973; Spencer, Bishop, Dawson, & Goodman, 2005). During intense segments (>85% VO_{2max}) energy production shifts to accommodate the increased demand for ATP. As intensity of exercise approaches maximal exertion, a combination of aerobic and anaerobic metabolic pathways must quickly meet the increased energy demand for optimal performance (Brooks, Fahey, & Baldwin, 2005; Coyle et al., 1985; Horowitz and Coyle, 1993; Montain et al., 1991; Saltin, 1973; Wu et al., 2006; Yaspelkis et al., 1993; van Loon et al., 2001). Alternating energy producing pathways during high intensity intermittent exercise quickly depletes glycogen (i.e. glucose) stores and metabolites for energy production, possibly leading to reduced exercise performance if glycogen is limited (Bergstrom et al., 1967; Coyle, Coggan, Hemmert, & Ivy, 1986; Saltin, 1973; van Loon et al., 2001). Hence of utmost importance is that athletes engaging in high intensity intermittent exercise such as soccer are provided with an ideal pre-exercise dietary provision to ensure that energy is produced preferentially from fat oxidation rather than carbohydrate oxidation so optimum performance can be achieved.

2.3.2. Pre-exercise Nutritional Requirements for Optimal Performance

Providing athletes with pre-exercise energy intake has proven beneficial for improved exercise performance when compared to exercise performed without prior energy intake (Jentjens & Jeukendrup, 2003; Moseley et al., 2003). Traditionally, an endurance athlete's primary pre-exercise meal consists of high GI carbohydrates and very little protein and fat (Rodriguez et al., 2009; Burke et al., 2005), which is believed to be ideal for the provision, maintenance, and replenishment of endogenous carbohydrate stores. This is thought to lead to optimal exercise performance (Burke, 1998b; Hargreaves, 2001; Hargreaves et al., 2004; Kreider et al., 2010). The ideal macronutrient composition of pre-exercise fuel for athletes of high intensity intermittent exercise is still being investigated but the requirement of energy intake for optimal exercise performance has remained constant (Burke et al., 2001; Krieder et al., 2010; Rodriguez et al., 2009). Throughout the days and hours prior to exercise athletes must consume adequate energy from liquid or solid foods for maximum exercise performance. Importantly, adequate pre-exercise meal consumption, as with consumption of any food, is regulated by a variety of nutritional, physiological, cognitive and sensory factors, and these factors should be considered in the planning and delivery of a pre-exercise meal to enable maximum performance outcomes (Birch, 1999; Conner & Armitage, 2002; Deibert, Koenig, Dickhuth, & Berg, 2005; Sorensen, Moller, Flint, Martens, & Raben, 2003).

Carbohydrates should be the primary component of any athlete's pre-exercise meal, and should supply 2.0-3.0 g available carbohydrate· kg bw^{-1} 3-4 hours prior to exercise or 1.0-2.0 grams available carbohydrate· kg bw^{-1} 1 hour prior to exercise to achieve improved performance (Burke, 2005; Kirkendall, 2004; IOM, 2005). Typically, the relationship between the amount of carbohydrate delivered to an athlete and time to exercise bout is proportional, where the amount of carbohydrate delivered increases as post-prandial time before exercise increases (Hargreaves et al., 2004; IOM, 2005; Rodriguez et al., 2009). An ideal carbohydrate to protein ratio of a snack or meal, to elicit muscle glycogen and protein synthesis, provides three parts carbohydrate to one part protein (3:1 CHO: PRO) (Kreider et al., 2011). Muscle protein repair and synthesis is enabled by a positive endogenous total amino acid pool which occurs after exogenous protein intake. The addition of protein to a pre-exercise meal, to provide the aforementioned exogenous protein, can alter and assist the post-prandial physiological hormone response, which may be a key mechanism by which performance and recovery can be improved (Betts, 2005, Ivy, 2003, Tipton, 2001; Wolfe, 2000; Brinkley, Green, & Jenkins, 2007; Blomstrand, 2001). A moderate protein component, 0.6-1.0 g protein·kg bw^{-1} 3-4 h before exercise, of a pre-exercise meal could also alter the glycemic response as amino acids are thought to reduce the GI of a carbohydrate source (Walton & Rhodes, 1997). Amino acids may elevate post-prandial circulating insulin and facilitate the removal of glucose from the blood following consumption of a pre-exercise meal (Betts, 2005; Spiller, Jensen, Pattison, Chick, Whittam & Scala, 1987). A low GI pre-exercise meal also containing good quality protein may therefore provide the ideal macronutrient provision to an athlete for optimal performance outcomes (Wolfe, 2000, Tipton, 2001). A minimal fat component (i.e. less than 5 grams/meal) should be present in a pre-exercise meal, as it helps control glycemic responses if a high glycemic carbohydrate source is consumed (Leuholtz & Kreider, 2001; Mondazzi & Arcelli, 2009; Rodriguez et al., 2009). Pre-exercise meals with an excessive fat content can inhibit digestion and absorption of more crucial macronutrients such as carbohydrate and protein (Rodriguez et al., 2009). Fibre content of a pre-exercise meal should not interfere with consumption of adequate macronutrient or energy amounts for optimal exercise. Pre-exercise meals with excessive fibre content may impede adequate energy or nutrient consumption via increased or expedited feelings of fullness or satiety cues from difficulties in mastication or ease of chewing and swallowing (Deibert et al., 2005). Ideal fibre content of a pre-exercise meal should enable prompt gastric emptying and not result in detrimental digestive symptoms, such as severe bloating, flatulence, or cramping during post-prandial or exercise periods (Deibert et al., 2005; Kreider et al., 2011; Rodriguez et al., 2009).

Effects of a pre-exercise meal on an athlete's gastrointestinal health should be considered when designing an ideal pre-exercise meal as many elite athletes, especially those of sports requiring endurance or high intensity exercise with high mechanical strain such as running or soccer, frequently experience problematic gastrointestinal distress (Deibert et al., 2005; van Niewenhoven et al., 2004). Compromised exercise performance from gastrointestinal disturbances is most often affected by issues of athlete nutrition, external environmental factors such as temperature and humidity, and physiological functioning of the upper and lower gastrointestinal tract (Deibert et al., 2005; Gisolfi, 2000). The majority of research involving athlete gastrointestinal health has focused on the effects of gastrointestinal disturbance on exercise, not necessarily the effects of pre-exercise nutrition on gastrointestinal function and symptoms such as abdominal pain, diarrhea, nausea, vomiting, belching, bloating, abdominal cramping, flatulence, and defecation that may affect exercise performance (Deibert et al., 2005; Brouns, 1991; Brown, Ketelaar, & Schulze-Delrieu, 1994; Bi & Triadafilopoulos, 2003; Collings et al., 2003; Peters et al., 1999). Affected athletes are recommended to implement preventative strategies such as maintaining hydration status, increasing time between eating and training, limiting intake of gas-forming foods, incorporation of new foods gradually, avoidance of caffeine, and experimenting with liquid pre-exercise nutrition (Simons & Kennedy, 2004). The importance of an athlete's gastrointestinal tolerability and acceptability of a pre-exercise meal should be recognized when designing an ideal pre-exercise meal to minimize the occurrence of gastrointestinal disturbances that interfere with exercise performance.

In addition to gastrointestinal acceptability and provision of adequate nutrition for optimal exercise performance, an ideal pre-exercise meal for athletes of high intensity intermittent exercise should also consider sensory perceptions, tolerability, and food familiarity (Barr, 1987; Birch, 1999; Brouns et al., 1998a; Brouns et al., 1998b; Rodriguez et al., 2009; Sorenson et al., 2003). Design, development, and determination of an acceptable pre-exercise meal for athletes necessitate the assessment of various sensory and digestive factors affecting consumption or appetite (Deibert et al., 2005; DOC, 2010). Two assessment methods are typically used when investigating human appetite: visual analogue scales and fixed point scales (Sorenson et al., 2003). Fixed-point scales use a numerical scale, with each point often indicating numerical or wording implications (Aiken, 1996; Guy-Grand et al. 1994). Outcome interpretation from a fixed point sensory assessment, such as a scale assessing palatability of a pre-exercise meal, require understanding some of the commonly used terms and are provided in the table below (Table 2.2).

Table 2.2: Sensory science terminology[1]

Appetite[1, 2]	A general term of overall sensations related to food intake, or a sensation related to maintenance of eating.
Satiety[2]	Satiation (within-meal): a process which leads to the termination of a meal. Satiety (between-meal): the state of inhibition of eating, or the influence on the time interval until the next eating episode.
Hunger[2]	A nagging, irritating feeling that signifies food deprivation to a degree that the next eating episode should take place.
Fullness[1]	A sensation of the degree of stomach filling, and prospective food consumption as an indicator of the supposed amount of forth coming food intake.
Palatability[3]	A hedonic evaluation of oro-sensory (taste, smell, texture, temperature, visual appearance, sound, and trigeminal input) food cues under standardized conditions.

[1] Adapted from Sorenson et al., 2003
[2]Blundell & Rogers, 1991
[3]Guy-Grand et al., 1994

Fixed-point scales are commonly used for various psychiatric evaluations of depression, schizophrenia, and psychopathological disorders and diseases (Aiken, 1996; Aiken, 2002; Dupuy H. 1984; Revicki et al., 1996; Svedlund et al., 1988). Gastrointestinal symptoms associated with disease, disorder and appetite have also been assessed using fixed-point scales to accurately assess the severity of symptom experienced by a participant (Damen et al., 2012; Revicki et al., 2004; van Munster et al., 1995). Fixed-point or Likert-type scales have previously been used to quantify and qualify the sensory perceptions and physiological digestive symptoms experienced after meal consumption (Aiken, 2002; Clason & Dormondy, 1994). Visual analogue scales are common when investigating human appetite and utilize horizontal lines with opposite statements in response to a question positioned at either end of the line (Hill, Lynn, Blundell, & Blundell, 1984; Yeomans & Symes, 1999). Responses are obtained as subjects score present perceptions of the question relative to the two opposing statements at either end of the pre-measured horizontal line with a mark (Sorenson et al., 2003). Participants' perceptions can then be quantified by measuring the distance of their mark from the left end of the line. Both visual analogue scales and fixed point scales enable the production of quantitative data; however, the data obtained from a fixed point scale can be tailored to obtain specific responses on a defined scale (Sorenson et al., 2003). Visual analogue scales provide adequate reproducibility when used for within subject designs and have some ability to predict feeding behavior (Stubbs, Hughes, Johnstone, Rowley, Reid, Elia, Stratton, Delargy, King, & Blundell, 2000). Assessment of mean post-prandial appetite ratings with visual analogue scales can be validated with as few as eight subjects; however, in paired designs a minimum of 18 subjects are required to minimize risk of 'false-negative' results (Flint, Raben, Blundell, & Astrup, 1999). Fixed-point scales can provide responses of greater variation, complexity and structure compared to visual analogue scales, as well as concrete ranks on a scale to improve ease and accuracy of quantitative analysis (Sorenson et al., 2003; Yeomans & Symes, 1999).

Athletes' perceptions of a pre-exercise meal's palatability properties such as taste, smell, temperature, texture and visual appearance can positively or negatively influence the type of food selected and the amount of meal consumed (Sorensen et al., 2003). Palatability is often assessed with questions like 'how pleasant have you found the food?', 'how attractive do you find the food?' or 'how do you find the aroma of the food?' (Sorensen et al., 2003) Research tools investigating an athlete's sensory perceptions of a pre-exercise meal should include questions such as 'how did the meal look?', 'what did you think of the size of the meal?', 'is the aroma of the meal appealing?', and 'the flavour of the meal was…?' to efficiently assess meal palatability and acceptability. Questionnaire item responses may include specifically-worded scale ratings or ranks such as 'not appealing', 'somewhat appealing', 'neutral', 'appealing', and 'very appealing' to which a numeric score can be associated, enabling accurate statistical assessment (Aiken, 2002). Quantifiable outcomes of sensory meal analyses can contribute to future manipulations improving meal palatability and acceptability. Therefore, meals designed to facilitate consumption of recommended carbohydrate and energy amounts for athletes of high intensity intermittent or endurance sport should have acceptable appetite and palatability requirements as these characteristics can affect meal consumption and subsequent exercise performance (Little et al, 2010; Birch, 1999).

2.4. Lentils: An Overview

2.4.1. Nutritional Profile

According to Pulse Canada (2013) legumes, including: soybeans and peanuts; pulses: dried peas, dried beans, chickpeas, and lentils; and fresh peas and fresh beans; are plants whose fruit or seed is enclosed in a pod. Pulses, as mentioned above, are part of the legume family; however, the term pulse only applies to the seed: dried fruit, from the leguminous pod (Pulse Canada, 2012). Pulses are typically low in fat, and high in fibre, protein and carbohydrate (Pulse Canada, 2012). Lentils, a dried seed of the *Lens Culinaris* plant, are pulses and have many unique characteristics that make them a beneficial addition to the diets of all individuals, and specifically athletes including: high-fibre health benefits, a low glycemic index, high protein content, phytochemical non-nutrient compounds, and satiety and fullness advantages (Amarowicz et al., 2007; Champ, 2002; Lam & Lumen, 2003; Grant, Duncan, Alonso, & Marco, 2003). Typically, Canadian diets have only included certain members of the legume family, such as black beans, navy beans, kidney beans, and white beans, while dried yellow and green split peas, dried fava beans, and lentils are less typically consumed (Grant, 2003; Ipsos-Reid, 2010; Iqbal, Khalil, Ateeq, & Kahan, 2006). The macronutrient composition of lentils may be described as the carbohydrate-protein-lipid-profile, and is a key trait generating beneficial health characteristics of lentils. Lentils are comprised of approximately 60-65% carbohydrate, 30-35% protein and 1% fat, and have a carbohydrate-protein-lipid-profile unlike other legumes (Iqbal et al., 2006; Wang & Daun, 2004). Other legumes have carbohydrate-protein-lipid-profiles with greater proportions of fat and carbohydrates, and lower protein content. The key nutritional characteristics of whole red "Robin" lentils, including the macronutrient amounts per 100 g dry are depicted below in Table 2.3. As a result of the unique macronutrient profile of lentils which provides high protein content, slow digesting carbohydrates (starches: amylose and amylopectin), and high dietary fibre, they have a very low GI of 30 (Foster-Powell & Brand-Miller, 2002; Jenkins et al., 1981; Lee et al., 2003). High-fibre lentils in an athlete's diet would contribute to sufficient dietary fibre intake, which is effective in improving blood lipid profiles and gut and colon health, preventing colon cancer, enhancing insulin sensitivity and glycemic control, and improving body composition (Anderson & Major, 2001; Bazzano et al., 2011; Mathers, 2002; Raben et al., 1997; Shai et al., 2008). Also, many of the health attributes associated with pulse crops, specifically lentils, are due to non-nutritive metabolites such as enzyme inhibitors, lectins, phytates, and phenols. Improvements in colorectal health, management of diabetes, and prevention and management of cancer have been identified as positive health outcomes due to lectins, phytates, enzyme inhibitors and saponins in pulses (Champ, 2002; Lajolo & Genovese, 2002). Enhanced immune function, cardiovascular health, and blood lipid profiles can be attributed to pulse crop soluble fibre, oligosaccharides, amino acids, and phenolic compounds like tannins and flavonoids with antioxidant capacity to reduce susceptibility to oxidative stress (Armarowicz, Karamc, & Shahidi, 2007; Mathers, 2007; Rizkalla, Bellisle, & Slama, 2002).

Table 2.3: Nutritional information for whole red lentils per 100 grams dry weight

Nutrient	**Amount/ 100g dry**	**% Daily Value**
Energy	302 kcal	
Fat	1.0 g	2
Total Carbohydrate	59.1 g	20
Starch	43.1 g	
Sucrose	1.8 g	
Fibre	14.2 g	57
Insoluble Fibre	12.4 g	
Soluble Fibre	1.8 g	
Protein	28.4 g	
Calcium	97.3 mg	10
Iron	7.3 mg	41
Potassium	1,135 mg	32
Vitamin C	0.7 mg	1
Thiamin	0.3 mg	23
Riboflavin	0.3 mg	18
Niacin	1.7 mg	9
Vitamin B_6	0.3 mg	14
Folate	186 μg	47
Selenium	8.2 μg	

Table contents adapted from Canadian Lentils, a Pulse Canada Publication. All macronutrients are expressed as g /100 g dry, and all micronutrients and minerals are expressed as mg or μg/ 100g dry. Percent Daily Value is based upon the Daily Value recommendations for nutrient amounts in a 2000 kcal daily intake (DOC, 2012). http://www.pulsecanada.com/food-health/composition-functionality, accessed 05/09/2012.

The nutritional profile of pulses, specifically lentils make them an excellent candidate for improved health outcomes in the general population. Athletes especially would benefit from regular dietary practices including lentils and other pulses, not only from the unique lentil macronutrient profile but also from the ability of the antioxidant compounds to battle the increased oxidative stress associated with high intensity exercise (Rodriguez et al., 2009).

2.4.2. Consumption and Benefits

At the time this research was conducted little research existed investigating the health benefits of pulses or lentils; or, on the effects of cognitive and practical barriers on pulse and lentil consumption. One study that reviewed the available Canadian dietary intake information regarding pulses and meats and alternatives identified a general deficit in public knowledge regarding health benefits of lentils, and low prevalence of pulse-based consumption (Froese, 2006). This review recommended future collection of relevant and reliable pulse consumption data, and consumer knowledge and cognitive concepts, such as attitudes and beliefs toward pulses (Froese, 2006). As of late much more research, with motives to improve legume, pulse and wholegrain consumption, has investigated and identified gaps in consumer knowledge, attitudes, beliefs, barriers affecting legume, pulse, and wholegrain intake patterns (Drewnowski, 2010; Gellar, Rovner, & Nansel, 2009; Ipsos-Reid, 2010; Veenstra, Duncan, Cryne, Deschambault, Boye, Benali, Marcotte, Tosh, Farnsworth, & Wright, 2010). As most Canadians, athletes seldom choose lentils or pulses; hence, to increase consumption it is crucial to identify concepts inhibiting pulse consumption to enable generation of mechanisms to alter negative perceptions and dietary patterns (Ipsos-Reid, 2010).

Healthy eating, including regular pulse consumption, involves concepts of social and individual determinants, health benefits, and attitudes and beliefs (Public Health Agency of Canada, 2001). A positive relationship exists between nutrition knowledge and healthy eating (Wardle & Steptoe, 2003). Several research studies investigating the relationship between nutrition knowledge and fruit and vegetable consumption have shown the enhancement of public nutrition and health knowledge of a food may lead to increased consumption of healthy foods (Gibson et al., 1998; Kearney, Kearney, Dunne, & Gibney, 1999; Lea,Woresly, & Crawford, 2005; Ma et al., 2002; Trudeau, Kristal, Li, & Patterson, 1998; Wansink, Westgren, & Cheney, 2005; Wardle & Steptoe, 2003; Werblow, Fox, & Henneman, 1978). Successful ventures to increase consumption employing public nutrition knowledge education have also been applied to promote nutritional benefits associated with various other foods: soy bean products, milk products, almonds, flaxseed, and pre- and pro-biotics (Armarowicz et al., 2007, Wang, 2004;

Champ, 2002; Wardle & Parmenter, 2000). Increased awareness in the general population of the health benefits of lentils, such as improved blood glucose maintenance, blood lipid profile, blood pressure levels, weight management, and improved satiety, could be key to observing changes in domestic pulse intake patterns (Froese, 2006, Grant et al., 2003; Wardle & Parmenter, 2000; Patterson, Kristal, & White, 1996; Hearty, McCarthy, Kearney, & Gibney, 2007, Hinton, Stanfod, Davidson, Yakushko, & Beck, 2004, Parmenter & Wardle, 2000).

An additional health attribute of lentils is the satiety and prolonged fullness caused by the protein and fibre content, which may reduce tendencies towards excess energy consumption and assist in weight management (Iqbal, 2006). However, the high fibre content has been labeled as a negative attribute as many suggest oligosaccharides present in pulses cause increased flatulence and gastrointestinal distress. This barrier was recently dispelled by the work of Veenstra et al., (2010) whose research did not identify significant differences in bloating or cramping when pulses were compared to potatoes over one month. Additional benefits of adequate amounts of fibre and protein in a meal also can reduce overeating tendencies through physiological fullness signaling (Iqbal, 2006). Lentils are a high source of protein, providing over 9 grams of protein in a 100 gram boiled portion, and increase ingestion time as a result of prolonged mastication. Lentils are also an excellent source of fibre and can aid in the reduction of elevated endogenous cholesterol levels, increase gastric output and reduce the risk of colon cancer (Mathers, 2002).

Saskatchewan is the world's top producer and exporter of lentils; however, the majority of Saskatchewan and Canadian residents seldom consume lentils (Froese, 2006; Pulse Canada, 2007). Lentil consumption is not only affected by the aforementioned cognitive concepts and limited awareness of health benefits, but also insufficient knowledge regarding preparation and economic advantages (Balch et al., 1997; Birch et al., 1999; Froese, 2006). Traditional or family oriented learned dietary patterns contribute to food choices. For example, if an individual is not exposed to lentil preparation or consumption through development, the probability of regular dietary incorporation later in life is low (Birch, 1999; Drewnowski, 1997; Mendelson et al., 2002). As a result, the public and private sectors have attempted to increase awareness of the health benefits of lentils and educate consumers on methods of dietary incorporation, ease preparation and consumption with processing and marketing techniques (Pulse Can. 2009, Sask. Pulse 2009).

2.5. Evaluating Athlete Nutrition Knowledge, and Attitudes, Beliefs & Barriers of Pulses

Many concepts are involved in an individual's dietary choices, such as nutrition knowledge, personal and social attitudes, and cognitive nutritional beliefs and barriers (Aiken, 1996; Aiken, 2002; Armitage & Conner, 2000; Birch, 1999; Fishbein, 1975; Trudeau et al., 1998; Turrell, 1998). Specifically, an athlete's dietary choices are influenced by lifestyle, time and financial management, social pressures, nutrition knowledge and culinary experience (Heaney, O'Conner, Naughton, & Gifford, 2008). The identification and quantification of the aforementioned concepts can provide information to assist in altering dietary behaviors and improving athlete nutrition; for example, the identification of a negative predisposition or behavioural intention toward a food can facilitate the development of mechanisms to alter the negative perceptions (Balch et al., 1997; Campbell, DeVellis, Strecher, Ammerman, Devellis, & Sandler, 1994; Drewnowski, 1997; Glanz, Basil, Maibach, Goldberg, & Snyder, 1998). Specifically, if the psychosocial concepts interfering with consumption of food can be identified and quantified, specific methods and programs could be developed and employed to alter the impeding concepts and resultant consumption behaviour.

The psychosocial concept of attitude, which is a learned predisposition to respond in a consistently favourable or unfavourable manner with respect to a given object, influences food selection patterns (Aiken, 2002; Trudeau et al., 1998). A belief links an object to a specific attribute; a stronger learned predisposition than an attitude, beliefs have profound effects on behaviour (Aiken, 2002; Cox, Anderson, Lean, & Mela, 1998; Fishbein, 1975). For example, an individual may believe white bread is not healthy and thus chooses to never consume white bread. The strength of negative belief linked to white bread directly influences the action or behaviour of white bread consumption. Attitudes and beliefs regarding an item govern the behavior toward the item; concisely, ideas about an item produce the action toward the item. By definition, behaviour is an observed measure of attitudes and beliefs toward an object; however, a behavior cannot be directly measured with a written examination tool as questionnaires can only assess information indirectly. Rather than direct assessment of behaviour, a questionnaire investigates a behavioural intention, a predictive concept for synonymous behavior (Aiken, 1996; Aiken, 2002; Fishbein, 1975, Fitz-Gibbon, 1987; Rosenstock et al., 1974; Rogers et al., 2005).

The effects of attitudes and beliefs on behaviour can be predicted employing two previously developed psychosocial models; specifically the health belief model and the diffusion of innovations model (Rogers et al., 2005; Rosenstock et al., 1974). The health belief model attributes behaviour execution to beliefs rather than barriers regarding specific health behaviour; whereas, the diffusion of innovations model attributes new behaviour to the perception it greatly surpasses the benefits of the practiced current behaviour (Rogers et al., 2005; Rosenstock et al., 1974). Lea et al, (2006) employed a questionnaire investigating psychosocial factors of practical and attitudinal barriers toward plant-based meals using the health beliefs model, and identified correlations between reduced plant-based intake and lack of information regarding plant-based diets and food preparation, time constraints, and negative attitudinal barriers. Similar practical and attitudinal barriers as those investigated by Lea et al., (2006) have been identified as factors involved in the dietary patterns of athletes (Heaney et al., 2008; Lea & Worsley, 2005). The parameters and methodology of the aforementioned plant-based intake assessment could be applicable to similar research regarding pulse-based intake investigation; therefore, enabling assessment of knowledge and negative psychosocial concepts that may interfere with lentil consumption. The development of a questionnaire investigating attitudes, beliefs and barriers toward pulses, specifically lentils, employing the two previous models may accurately assess associations between the aforementioned psychosocial concepts and pulse consumption behaviors in young athletes (Ma et al., 2002; Nejad, Wetheim, & Greenwood, 2005; Patterson et al., 1996; Trudeau et al., 1998).

Questionnaires are designed and developed as a comprehensive assessment tool to investigate the aforementioned concepts toward a specific topic or a group of objects or ideas. To do this, specific themes or groups can be created within a questionnaire; for example, several items could be grouped into themes such as exercise nutrition knowledge, carbohydrate knowledge, or protein knowledge for more specific quantification when investigating general nutritional knowledge (Aiken, 1996; Parmenter & Wardle, 1999; Wardle & Parmenter, 2000). Quantification of the questionnaire using numerical scores assigned to the concepts investigated, can then determine an overall score for general nutrition knowledge, as well as individual scores for each theme/group within the questionnaire's overall scope (Clason & Dormondy, 1994; Fitz-Gibbon, 1987). The resulting quantitative outcomes can be used to develop methods and materials such as educational tools, advertisements, and product marketing to improve consumption levels via alteration of negative concepts toward an item, such as pulse crops (Campbell et al., 1994; Cox, et al., 1998; Lea et al., 2006; Wardle & Parmenter, 2000).

Athletes of intense exercise require specialized nutrition to maximize training and performance; and, nutrition knowledge is one of the most influential concepts involved in adequate dietary intake practices for sport (Wardle & Parmenter, 2000). The concept or quantification of nutrition knowledge in adults encompasses several genres: the understanding of terms, awareness of dietary recommendations and diet-disease associations, food specific nutrient information, and the use of information in dietary choices (Parmenter & Wardle, 1999). Athlete nutrition knowledge, as assessed by Zawila, Steib, & Hoogenboon, (2003), employed a 76-item questionnaire investigating concepts of specific athlete nutrition knowledge, general nutrition knowledge of macro- and micronutrients, hydration, diet-related health outcomes, and healthy eating attitudes (Barr, 1987; Werblow et al., 1978; Zawila et al., 2003). Quantification of nutrition knowledge levels in athletes can be beneficial to identify effects of nutrition knowledge on consumption patterns, and the development of educational strategies to translate positive concepts to beneficial behaviours (Hearty et al., 2007). A validated questionnaire, such as the one of Zawila et al. (2003), could be used to efficiently assess the nutrition knowledge of athletes and provide insight into their regular dietary practices.

2.6. Lentils for Athletes

Nutrition is the most influential variable that affects an athlete's performance and improper diet often limits the results (Krieder et al., 2010; Rodriguez et al., 2009). Lentils are advantageous as part of an athlete's diet, as they provide a perfect balance of the most important macronutrients: carbohydrate and protein (Krieder et al., 2010). A combination of foods is most often required to achieve recommended pre-exercise intake amounts; however, lentils deliver these amounts in whole food form. They not only provide slow digesting carbohydrates to ensure blood glucose levels are maintained and glycogen degradation prevented, but also act as a high protein source to facilitate muscle protein synthesis and repair (Mondazzi & Arcelli, 2009; Rodriguez et al., 2009). The high fibre content of lentils may also be beneficial for athletes, especially those required to monitor body mass for weight regulated competition; as high daily dietary fibre intake can reduce total caloric intake (Anderson & Major, 2001; Bazzano et al., 2011; Harman et al., 2010; Mathers, 2002; Raben et al., 1997; Shai et al., 2008). Athletes may benefit in the latter aspects of their sport performance if a low glycemic load pre-exercise meal is consumed as low GI pre-exercise intake may preserve endogenous carbohydrate stores for use in latter portions of exercise and improve performance (Mondazzi & Arcelli, 2009). Lentils may therefore be a convenient whole food able to provide athletes with the ideal macronutrient profile for optimal sport performance; hence, I studied lentils as an ideal pre-exercise meal for athletes of high intensity intermittent exercise.

CHAPTER 3: OBJECTIVES

3.1. Rationale

In this work, a soccer-based exercise study was performed to investigate if lentils can provide optimal pre-exercise fuel for athletes performing high intensity intermittent exercise. Overall, this research was designed to assess various aims in several disciplines; specifically, sport nutrition, exercise physiology, and agriculture.

The ideal pre-exercise meal for athletes of high intensity intermittent exercise has yet to be determined by international sport nutrition authorities such as the International Society of Sports Nutrition or the American College of Sports Medicine. Lentils have a unique macronutrient profile providing an excellent source of low glycemic index carbohydrate, high levels of lysine-rich protein, high fibre content, and low fat content. The consumption of lentils leads to the slow prolonged release of glucose into the circulation and as such produces a low glycemic response, theoretically preserving an athlete's energy stores for improved performance in the latter stages of an exercise bout. Primarily, pre-exercise meals for athletes of intense exercise must provide adequate energy and macronutrient amounts to fuel the athlete for optimal performance; however, a pre-exercise meal should also, act as an acceptable and tolerable sensory and digestive vehicle to deliver the required fuel (Rodriguez et al., 2009). To ensure adequate sensory acceptability of the pre-exercise meals delivered in this exercise study a sensory meal analysis was constructed to assess the participant's perceptions toward meal palatability. The importance of an athlete's gastrointestinal tolerability of a pre-exercise meal was assessed in this study. Throughout testing, the participants rated the severity of digestive symptoms which aided in the determination of pre-exercise meal acceptability. In this research study, both the athlete's sensory perceptions and digestive symptoms were qualified and quantified with a fixed-point Likert-type scale (Aiken, 2002; Clason & Dormondy, 1994).

The majority of pulses, primarily lentils, but also chickpeas, dried yellow and green peas, and dried beans, produced in Saskatchewan are primarily exported, as local processing and consumption of these products is minimal (Pulse Canada, 2009). Lentils behold many nutrient and non-nutrient characteristics whose properties can produce a variety of health benefits when consumed as part of a balanced dietary regime according recommendations from Health Canada. Increasing local lentil and pulse consumption would benefit the pulse-based agricultural economy and possibly lead to improved population health. As improvements in consumption behaviours require the identification and modification of the detrimental psychosocial and cognitive concepts of beliefs and attitudes that generate the behavior, this study also assessed the athletes' nutrition knowledge, and attitudes and beliefs towards lentils with a questionnaire adapted from two previous investigations: a plant-based intake assessment performed by Lea et al. (2006) and an athlete specific nutrition knowledge questionnaire performed by Zawila et al. (2003). The parameters and methodology of the above-mentioned assessments warranted application of a similar research design to this athlete-specific pulse-based investigation with the aim to utilize the generated tool for future pulse-based investigations.

Soccer has the highest participation rate of any other sport in the world (FIFA, 2007; Reilly, 2003) as it does not require any special equipment and is inexpensive to play. High pulse and legume consumption levels may also be observed in many of the countries where soccer participation levels are high (FIFA, 2007; Reilly, 2003). Initial ideas incorporated into this study design were based on hypothetical identification of improved exercise performance from lentil consumption, and the resultant successful marketing and development of a lentil-based sport nutrition product. Influencing the purchase and consumption of lentils with sport-based marketing may positively affect the general public's favourable tendencies towards lentils, and also positively influence the levels of national pulse consumption (Sorensen et al., 2003). Therefore, an objective of the overall research study was to measure the effects of a lentil pre-exercise meal on high intensity exercise performance. This work has been published (Little, Chilibeck, Ciona, & Zello, 2008; Little et al., 2010).

The nutritional attributes of lentils, the prevalence of pulse consumption in countries of high soccer participation rates, the socio-economic factors of pulse-crop production in Saskatchewan, and the marketing capabilities of sport warrants the investigation of lentils as an optimal pre-exercise fuel source for athletes of high intensity intermittent exercise. These attributes of lentils make them an ideal vehicle to provide key macronutrients and energy to athletes of high-intensity intermittent sport to achieve optimal exercise performance.

3.2. Statement of the Problem

Pilot study purpose: To determine the practicality and feasibility of a low glycemic lentil pre-exercise meal for soccer; to ensure meal portion and macronutrient amounts are suitable and provide adequate fuel for the athlete; to identify key sensory perceptions of the pre-exercise meals; and to identify the most significant digestive symptoms that require assessment.

Main study purpose: To determine the efficacy and acceptability of lentils as an optimal pre-exercise meal for athletes of high intensity intermittent exercise, and to investigate whether the macronutrient profile of lentils is able to provide these athletes with the fuel needed for maximal performance.

Research Question: Are lentils an optimal and acceptable pre-exercise meal for athletes of high intensity intermittent exercise?

3.3. Hypotheses and Objectives

3.3.1. Hypotheses

1. The sensory aspects of lentils as a pre-exercise meal for soccer trials will not differ from the sensory aspects of other pre-exercise meals.
2. The digestive symptoms relating to consuming a lentil pre-exercise meal will not differ from the digestive symptoms from equal amounts of other typical pre-exercise meals.
3. Adequate total energy (kcal·kg bw^{-1}) and/or carbohydrate (g·kg bw^{-1}) intake from a pre-exercise meal (60-100% of designed need) positively affects sport performance.
4. An individual's higher level of nutrition knowledge positively influences their attitudes (beliefs and barriers) towards pulse-based meals.

3.3.2. Objectives

Objective 1*:* To develop a pre-exercise lentil meal of low glycemic index for soccer trials.

Specific aim 1a: To examine the sensory aspects of the pre-exercise meal.

Specific aim 1b: To examine the post-prandial digestive symptoms of the pre-exercise meal.

Specific aim 1c: To investigate the effects of the pre-exercise meal on athletic performance.

Specific aim 1d: To investigate the influence of 24 hour energy and carbohydrate intake on athletic performance.

Objective 2: To develop and administer a questionnaire to assess nutritional knowledge, dietary patterns, and beliefs and barriers towards lentils in male athletes.

CHAPTER 4: PILOT STUDY

4.1. Methodology

4.1.1. Participants

Seven male athletes (age = 23.3 ± 3.8 y, VO_{2max} = 56.7 ± 5.0 $mL•kg^{-1}•min^{-1}$) volunteered for the pilot study. All athletes were experienced in interval training or a sport of high-intensity intermittent-type exercise, and with running on a treadmill. A Physical Activity Readiness Questionnaire (PAR-Q) was administered before testing. The study procedures and protocol were approved by the Biomedical Research Ethics Board at the University of Saskatchewan (Appendix A1.1), and participants completed a written consent form before any measurements were taken (Appendix A2.1).

4.1.2. Experimental Design

Pilot study participants were required to make five laboratory visits: preliminary tests, maximal oxygen uptake (VO_{2max}) and a treadmill-based simulated soccer trial familiarization (see Little et al., 2010 for details) were performed in the first two visits; and, three experimental trials were carried out in weekly visits. One experimental condition employed a fasted control condition, and two fed conditions employed a low GI (GI = ~29) lentil pre-exercise meal and a high GI (GI = ~81) potato pre-exercise meal both delivering 2.0 g total carbohydrate per kilogram body weight; and, all followed by a 3 hour post-prandial period and subsequent 90 minute simulated treadmill-based soccer trial (GI values from Foster-Powell et al., 2002). During the post-prandial period a Test Meal Analysis was administered to assess pre-exercise meal sensory acceptability and palatability. A single-blind, randomized counter-balanced design was employed in the execution of the experimental trials: only the researcher measuring exercise testing was blind to the employed experimental condition. At various time points throughout the post-prandial and exercise periods the participants rated pre-exercise meal induced post-prandial digestive symptom severity. The pilot study included a half-time meal an 8th of the size of the pre-exercise meal.

4.1.2.1. Details of Experimental Meal Conditions

The pilot study employed three conditions to investigate the feasibility of lentils as an optimal pre-exercise meal: an unfed fasted condition, low glycemic index (LGI) lentil condition, and a high glycemic index (HGI) instant mashed potato condition. The meals were designed to provide 2.0 g of total carbohydrate per kilogram of body weight, and were isocaloric, and matched for macronutrient content. The total energy and macronutrient profiles of the meals are presented in Table 4.1. No food was provided in the control condition.

Table 4.1: Energy content and macronutrient profile of the low and high GI pre-exercise and halftime meals (based on a 70 kg participant).

	Pre-exercise		Halftime	
	Low GI	High GI	Low GI	High GI
Energy (kcal)	~835	~835	~104	~104
Total Carbohydrate (g)	140	140	17.5	17.5
Protein (g)	62.7	63.0	7.9	7.9
Fat (g)	2.6	2.5	0.3	0.3
Glycemic Index (GI)	29	81	29	81

A control condition (no meal) was also employed. GI values for individual foods are from Foster-Powell et al. (2002). GI values for the high GI meals were calculated using the mixed meal method from Wolever and Jenkins (1986).

The low GI pre-exercise meal was prepared with Saskatchewan produced decorticated 'CDC Robin' red football lentils (GI = 29, SaskCan Pulse Trading, Regina, SK). Pulse Canada (2012) states that 100 grams of dry whole red Canadian lentils, as depicted in Table 2.3 above, contain 302 kcal energy, 59.1 g total carbohydrate, 14.2 g total dietary fibre, 28.4 g protein, and 1.0 g fat. The lentil meal was designed to provide 1.5 g available carbohydrate (i.e. total carbohydrate minus fibre) per kilogram body weight for each participant. Individual meal amounts were determined based on the macronutrient amounts of the dry nutrient analysis.

The second pilot study meal was designed to produce a high glycemic response, in contrast to the LGI lentil meal. This HGI meal consisted of instant mashed potatoes flakes (McCain Foods, Florenceville, NB), pasteurized raw egg whites (Burnbrae Farms, Upton, QC), margarine (generic non-hydrogenated canola oil), and ketchup (Heinz, North York, ON), and had a glycemic index (GI) of ~81 (GI values from Foster-Powell et al., 2002 using the mixed-meal method from Wolever and Jenkins, 1986). Egg whites were added to match the protein content of the lentils. Nutritional information of the test meal component foods is depicted in Table 4.2 below; these values were employed to generate the ingredient amounts for the potato test meals. The ingredient amounts required to obtain macronutrient equality to the lentil meal were 2.4 g dry instant mashed potato flakes, 1.5 g ketchup, 5.6 g raw egg whites, and 0.07 g margarine, all per kilogram body weight. The HGI meal components delivered the following macronutrient amounts: carbohydrate, 2.0 $g \cdot kg^{-1}$ body weight from instant mashed potatoes and ketchup; protein, 0.9 g·kg^{-1} body weight from egg whites; and fat, 0.04 g·kg^{-1} body weight from margarine.

Table 4.2: Macronutrient composition of component test foods.

Nutrient name	Protein (g)	Fat (g)	Carbohydrate (g)	Energy (kcal)	Fibre (g)	Sugars (g)
Lentil, whole, red	24.8	1.0	59.1	302	14.2	1.8
Tomato, ketchup	1.7	0.5	25.8	100	1.7	22.8
RTS Seasoned Mashed Potatoes	1.8	2.1	14.9	98	1.6	0.8
Egg, white, chicken, raw	10.2	0.0	0.8	47	0	0.7

Values for food items were obtained online from the Canadian Nutrient File and are per 100 g of edible portion. McCain RTS (Ready to Serve) Seasoned Instant Mashed Potato values were obtained from McCain Canada. Carbohydrate values include fibre amounts.

4.1.2.1.1. Details of Half-time Meal Delivery

After completion of the first half of the simulated soccer trial, 3 hours and 45 minutes after meal consumption, the participants were provided a small half-time meal, of identical preparation and delivery as the pre-exercise meal, designed to provide 0.25 grams of available carbohydrate per kilogram body weight. The half-time meal provided the athlete with one eighth of the energy and macronutrients in the pre-exercise meal portion.

4.1.2.2. Details of Test Meal Sensory Analysis

Participant’s appetite and sensory perceptions of the pre-exercise meals were assessed using a fixed-point rating scale examination tool according to previously validated and employed rating scales (De Graaf et al., 1999; Guy-Grand et al., 1994; Sorenson et al., 2003; Yeomans, 1996). An eight item test meal sensory analysis (Table 4.3) was compiled to investigate meal palatability, including characteristics of visual appearance, aroma, taste, texture, portion size, and ease of consumption (Aiken, 1996; Clason & Dormondy, 1994) (Appendix A3.2).

Within each question of the test meal sensory analysis were both quantitative and qualitative components enabling accurate assessment of the participants’ perceptions toward the pre-exercise meals. The quantitative component consisted of five ranks on a scale from negative to positive with specific wording implications for each question (see Appendix A3.2 for rating scale wording). The qualitative component consisted of a blank lined comment space wherein the participants could describe their response in detail.

Table 4.3: Test meal sensory analysis content.

Question	
1	How did the meal look?
2	What did you think about the size?
3	Did the meal have an aroma?
4	Is the aroma of the meal appealing?
5	What is the texture of the meal?
6	How did you find the ease of chewing and swallowing the meal?
7	The flavour of the meal was…?
8	Do you feel you will be able to exercise with ease at the beginning of the testing?

Eight questions investigating the palatability of the pre-exercise meals are listed below. The complete examination tool is located in Appendix A3.2.

4.1.2.3. Details of Digestive Symptoms Rating Scale

Severity of physiological digestive symptom severity experienced by the participants was assessed throughout experimental testing with a fixed-point rating scale. The generated scale contained five numerical ranks (0-4) quantifying symptom severity: where 0 = no symptoms, 1 = mild symptoms, 2 = moderate symptoms, 3 = moderately severe symptoms, and 4 = severe symptoms (Appendix A3.1). Symptoms assessed included fullness, bloating, nausea, abdominal cramping, headache, flatulence, and hunger.

4.1.2.4. Details of 24 hour Dietary and Activity Records

Possible diet-induced metabolic variability was minimized as participants were asked to complete a 24-h diet record. Following the familiarization trial participants were instructed to list all sources of calories consumed, volumes and quantities, 24 h prior to the first trial (Appendix A3.3). A trained nutrition researcher reviewed record accuracy with each participant. Potential effects of prior physical activity on metabolism and performance were limited as participants were asked to refrain from strenuous physical activity 24 h before each trial. Participants were asked to record their physical activity (Appendix A3.4), tracking training (intensity, time, and type), prior to the first experiment day and mimic the pattern for the subsequent trials. Both records were copied and returned to participants with instruction to reproduce the record 24 h prior to the next trial; adherence was assessed on each testing day.

4.1.2.5. Details of Exercise Tests

Preliminary procedures performed during the first two visits to the laboratory determined the participant's aerobic capacity and maximum speed at their aerobic capacity (Harling, Tong, & Mickleborough, 2003), and familiarized the participants with the treadmill (Vacu Med, Model 13622, Ventura, CA) and exercise protocol for the experimental trials. Specific details regarding the above protocol and calculation of athlete specific exercise testing protocols are available from Little et al., (2008), and Little et al., (2010). The treadmill-based exercise test was individualized for each participant according to their speed at VO_{2max}, as in Little et al., (2010).

The second visit had participants participate in a full treadmill based soccer-trial to familiarize them with speeds and procedures (Drust, Reilly, & Cable, 2000). The simulation was administered in standardized 15-minute blocks consisting of 6 walking (75 s), 6 jogging (40 s), 3 running (20 s), and 8 sprint (12 s) intervals (Table 4.4). Acceleration and deceleration between intervals was controlled with Turbofit 5.05 (Vacu Med, Ventura, CA) software and enabled individualization of the protocol for each participant. The first half of the trial included three identical 15-minute blocks and the second half included two identical 15-minute blocks plus a repeated sprint test in the last 15 minutes. The repeated sprint test consisted of five participant-guided 1-minute sprints; each separated by 2 minutes and 30 seconds of recovery, and is also described in detail by Little et al., (2010).

Table 4.4: The intensity of the walking, jogging, running, and sprinting intervals used in the treadmill soccer trial simulation expressed relative to peak treadmill speed (V_{max}).

Interval	**% V_{max}**
Walking (6 $km \cdot h^{-1}$)	34.0 ± 3.3
Jogging (10 $km \cdot h^{-1}$)	56.6 ± 6.6
Running (16-17 $km \cdot h^{-1}$)	93.3 ± 6.7
Sprinting (20-21 $km \cdot h^{-1}$)	114.9 ± 8.3

% V_{max} values are expressed as means ± SD.

4.1.3. Experimental Protocol

Fasted participants (minimum 10 h) arrived at the laboratory between 6:00 and 7:00 am, and were instructed in the proper manner to assess their digestive symptoms and were asked to complete a baseline gastrointestinal symptom assessment (Appendix A3.1). After baseline value collection, participants, unaware of the assigned experimental condition, were escorted to the meal delivery room to consume the provided experimental meal or continue fasting. Participants were told to complete the entire meal portion within 20 minutes. Incomplete consumption of the entire delivered portion of the test meal was compensated by adjustment of the following meal condition; the remaining meal condition was scaled to match the amount consumed in the first meal condition. The second measurement of digestive symptom severity was collected 15 minutes after meal consumption commenced and subsequently at 30, 60, 75, 90, 120, 180, 225, and 270 minutes throughout experimental testing. Following pre-exercise meal consumption the participants were instructed to complete one test meal analysis only after each the lentil and potato meal conditions (Appendix A3.2); completing both a quantitative rank scale and a qualitative comment section for each item. Upon completion, the sensory evaluation was collected by the research assistant. The volume of water consumed throughout testing was recorded, and the participant was informed that the volume consumed would have to be matched in subsequent trials. The participants were asked to remain relatively inactive throughout the post-prandial period and were allowed to watch TV, do homework, or work in the computer lab. Toward the end of the 3 hour post-prandial period, or the beginning of the exercise testing, the participant was asked to prepare for the exercise and return to the laboratory. Immediately prior to exercise, physiological and sensory assessments were again performed and the participant began a short warm up on the treadmill. Exercise testing began promptly at time zero and sensory and physiological parameters were assessed between all 15 min blocks. After 45 minutes consisting of three identical 15 minute segments, participants were allowed to rest 15 minutes. During the 15 minute "half-time" participants were provided a half-time meal providing1/8th of energy and macronutrients of the pre-exercise meal. Following half-time, participants then resumed the latter 45 minutes of the tests: 2 fifteen minute blocks and 1 block of repeated sprint testing. The participants were reminded to follow the 24 hour dietary record and 24 hour physical activity record as best they could the day prior to the next experimental testing day.

4.1.3.1. Pre-exercise Meal Administration and Analysis

Both pre-exercise test meals were prepared immediately prior to participant arrival on each testing day according to the randomized delivery of each experimental meal. When participants were to consume the lentil condition, the dry weight (grams) of lentils required to provide 2.0 grams total carbohydrate, ~240 grams dry lentils for a 70 kg participant, would be measured and transferred into a sieve. The lentils were then rinsed with cold water and placed into a large sauce pan. To the lentils water was added at 3 parts water to 1 part lentil. The lentils were cooked until soft and a pinch of salt was added at the end of the cooking process to prevent seed toughness and improve meal flavour.   The lentils were then placed in a storage container and transported to the meal delivery room for the participant to consume. Tomato paste was offered along with the lentils if participants required the addition to consume the delivered portion. If the potato meal was required on a testing day, meal preparation would begin with the measurement of the dry grams of instant mashed potato flakes, 2.4 g dry flakes$\cdot$kg^{-1} , required for each participant into a large tarred heat resistant vessel. According to manufacturer's directions the appropriate amount of boiling water was added to the flakes with a small amount of margarine, 0.1 g$\cdot$kg^{-1}, and the mixture was whipped with a hand blender until smooth. The potato mixture was reweighed in the tarred vessel to determine the wet grams prepared. Ketchup, 1.5 g$\cdot$kg^{-1}, was also weighed into the same vessel, after tarring, in the appropriate volume for each participant. Lastly, the egg whites, 5.6 mL/ kg, were weighed in a tarred vessel and cooked in a microwave oven until light and fluffy, and weighed. The cooked egg whites were then combined with the prepared potatoes and ketchup to obtain one total prepared meal amount (nearest tenth of a gram). All potato meal components were delivered in a single vessel to ensure that a macronutrient balance equivalent to that of the lentil meal was consumed. Any uneaten pre-exercise meal portions weighed to the nearest tenth of a gram, recorded and discarded. Consumed portions were divided by the prepared amount and individual participant consumption amounts were expressed as a percentage of designed delivered pre-exercise meal.

4.1.3.2. Analysis of Examination Tools

Quantitative ranks obtained from the test meal sensory analysis (Appendix A3.2) were compiled by analysis item for each fed condition for all the participants and average means were compared between the two fed conditions with dependent t-tests ($p<0.05$). Qualitative responses were also complied by analysis item and comments and criticisms were left for later interpretation. A post-prandial digestive symptom rating scale assessed physiological symptom severity associated with pre-exercise meal consumption and digestion. Initially data obtained from each subject's three complete scales were entered into Microsoft Excel (Microsoft Office 2007) spreadsheets grouped by experimental condition and each assessment point. Averages at each assessment point for each lentil, potato and control conditions were tabulated. Average severity of each fullness, bloating, nausea, abdominal cramping, headache, flatulence, and hunger for each condition at each time zone were compared to depict differences between the experimental conditions. Dietary records (Appendix A3.3) from the seven participants were entered into Diet Analysis+ 8.0 and total energy intake was calculated; and, within the program a profile containing the subjects weight (kg), height (cm), and age were generated. If a subject had not followed protocol and more than one intake record was generated, both records were entered to generate an average intake amount (kcal/day). Physical activity in the 24 h (Appendix A3.4) before exercise was also enter into Diet Analysis+ (version 8.0, Wadsworth/Nelson Education Ltd., Scarborough, ON) to determine energy expended in the day prior to testing. Values obtained from pilot study dietary intake and physical activity records were reviewed to ensure potential effects of energy intake and prior physical activity on exercise metabolism or performance was limited.

4.1.3.3. Exercise Testing Collection and Analysis

During the last 15 minute block of the simulated soccer match the participant's performance was assessed with a repeated sprint test consisting of 5 one minute sprints separated by 2.5 minutes rest. The participant's distance covered during the sprints was assessed with the digital distance output from the testing treadmill. The assessment was accurate to the every 16 meters. Average sprint distances (m) from each experimental condition were calculated from the seven participants. The participants also indicated their level of perceived physical exertion with the use of Borg's Ratings of Perceived Exertion (RPE) scale (6-20) at the end of each 15 minute exercise block (1975).

4.1.4. Statistics

Average consumption percentages for each experimental condition were generated from the 7 participant's consumed amounts. Differences between pre-exercise meal consumption amounts were investigated with a dependent t-test . Average sensory perceptions of the pre-exercise conditions were tested for significant differences using dependent t-tests for each item of the test meal analysis. Means of digestive symptom severity (7 digestive symptoms), and RPE for each experimental condition were analyzed for differences at each assessment point using a two-factor (meal condition x time) repeated measures ANOVA with Tukey's post hoc tests. Total sprint distance data did not reach assumptions of normality; as such results were analyzed with a Friedman repeated measures ANOVA on ranks. All results are expressed as means ± standard deviation (SD). Statistical analyses were performed on SPSS version 17.0, and significance was achieved at $p<0.05$.

4.2. Results

4.2.1. Pre-exercise Meal Consumption

On average, participants consumed 57 ± 24% of the potato pre-exercise meal and 71± 17% of the lentil pre-exercise meal with difference between meal consumption. The potato meal provided a total carbohydrate intake average of 1.0 ± 0.3 $g{\cdot}kg^{-1}$ while the lentil meal provided a total carbohydrate intake average of 1.1 ± 0.4 $g{\cdot}kg^{-1}$ with no significant differences in carbohydrate consumption between the lentil and potato conditions ($p<0.05$). The half-time meal consumption was not different between the two conditions and participants consumed an average of 79 ± 31% of the halftime food providing 0.19 ± 0.08 $g{\cdot}kg^{-1}$ of total carbohydrate.

4.2.2. Test Meal Analysis

The test meal analysis consisted of quantitative and qualitative components: eight quantitative (5-point Likert scale) sensory meal analysis questions were followed by a qualitative comment section in which the participants noted their pre-exercise meal opinions. Question one was designed to assess sensory perceptions of meal appearance. No differences were observed between the lentil and potato conditions, and all responses were rated identically as “somewhat appealing”, or the second of five ratings on the negative side of the scale. The lentil meal received an average rating of large and the potato meal received an average rating of cumbersome; however, there were no significant differences between the meal conditions. The third question aimed to assess meal aroma. On average the potato meal was rated to have an aroma, while the lentil meal was rated to not have an aroma ($p<0.05$). The next question assessed the appealing qualities of the meal aroma. The potato meal produced an “I don’t know” ranking on average and, contrarily to the rating of no aroma from the previous question the aroma of the lentil meal was rated as not appealing. The fifth question investigated meal texture and the sixth question assessed the ease of chewing and swallowing. The lentil and potato meals both received average ratings of 3 (neutral) in both questions. Question seven assessed the flavour of the meal, and both conditions received an average rating of “somewhat appealing” meal flavour. The last question assessed the participants’ ability to exercise after the post-prandial period, and the participants indicated on average that it would be fine to exercise at the start of the test in both conditions.

4.2.3. Post-prandial Digestive Symptoms Rating Scale

A main effect of meal condition on fullness was found ($p < 0.001$), and post hoc comparisons identified significant differences between each fed condition, lentil and potato, and control at all time-points except the initial and 8th collection points ($p < 0.05$). Immediate post-prandial data identified distinct differences in fullness severity between fed and control conditions, and a difference between lentil and potato (2.8 ± 0.11, 1.2 ± 0.08, 0.4 ± 0.05 for lentil, potato and control, respectively). Although not statistically significant, it should be noted the severity of fullness for the fed conditions steadily decreased as post-prandial and exercise periods progressed.

Bloating, abdominal cramping, headache, and flatulence symptoms were not significantly different between the experimental conditions at any time point ($p < 0.05$). A slight increase in the digestive symptom of nausea was seen in the lentil condition when compared to the other experimental conditions. The lentil meal was perceived as producing mild symptoms of nausea (1) while the potato and control meal were perceived as producing no symptoms of nausea (0). Post hoc analysis identified a more severe rating after consumption of the lentil meal at 165 minutes prior to exercise (time point 2 = -165 min, or 15 minutes post-prandially) than the potato meal and control (1.1 ± 0.09, 0.1 ± 0.09, 0.0 ± 0.02, respectively; $p=0.006$). No other significant differences in nausea were observed between conditions at any time point.

Meal condition also had a significant effect on hunger ($p < 0.01$). Post hoc tests demonstrated a significant difference in hunger severity between both fed conditions and the control at the second time-point, -165 minutes before exercise testing (0.01 ± 0.04, 0.04 ± 0.05, 1.7 ± 0.140 for lentil, potato and control, respectively). A significant difference in hunger symptom severity between control and fed conditions was also observed from -165 minute time point onwards, although no differences were observed between the fed conditions ($p < 0.05$).

Overall, the participants' recorded severity of bloating, abdominal cramping, headache, and flatulence were similar for all experimental conditions, with average ratings of zero, or no digestive symptom severity.

4.2.4. Physiological Parameters and Exercise Performance

A significant main effect of time on RPE was identified at latter assessment points during exercise testing: RPE was higher at 90 min compared to 15 min, and also higher 105 min compared to all other assessment points ($p<0.05$). No significant differences were identified between meal conditions at the individual assessment points for RPE.

A significant main effect was found for meal condition on performance ($p<0.05$) with distance covered in the low GI (1625 ± 205m) being significantly greater than control (1378 ± 361m). No differences in total sprint distance were observed between the lentil and potato (1603 ± 234m) meals, nor potato and control.

4.3. Discussion

The pilot study critically assessed the feasibility of the initial experimental design and protocol that we developed to investigate lentils as an optimal pre-exercise meal for high intensity intermittent exercise. Evaluation of the participants' negative and positive experiences, outcomes and results through the assessment of oral, written, and physical feedback enabled us to adjust the experimental protocol to improve main study (section 5.1) outcomes.

Pre-exercise meal administration, consumption and analysis outcomes of the pilot study prompted modifications in the main study meal delivery protocol and procedure. For instance, the pilot study meal components were combined and delivered in one vessel to reduce preferential food component selection (and wastage) and resultant macronutrient intake variability; however, participants expressed an extreme dislike for the mixed delivery style, particularly in the potato meal. Therefore for the main study meal, components were prepared, measured, delivered and consumed separately in an attempt to improve sensory acceptability of the meals. Participant feedback also encouraged alterations of the high glycemic meal. The test meal analysis identified both pre-exercise meal sizes as large or cumbersome, and percentage of meal consumption (57 ± 24% potato meal, 71± 17% lentil meal) reinforced the executed modifications. Some of the potato meals approached 1500 g for some participants and were not entirely consumed due to the size, texture and taste; as such, we replaced some of the potatoes with white bread to improve consumption and maintain macronutrient design. Finally, poor acceptance despite moderate consumption of over 70% of the half-time meal resulted in the deletion of the half-time meal from the experimental design.

The qualitative feedback from the pilot study participants with regards to their sensory perceptions of the pre-exercise meal prompted alterations to the test meal analysis assessment tool. The pilot study test meal analysis contained 8 questions: 5 questions answered using individualized fixed-point Likert scales, and 3 questions answered using a 3-point Likert scale with the choices of yes, no, and I don't know (Table 4.3). All 8 questions also contained qualitative comment sections. While questions 1 and 2 were unaltered in the main study test meal analysis, question 3 was changed to assess meal consumption with a 5-point scale, and questions 4 and 5 assessed meal aroma and aromatic tolerance, respectively, both with a 3-point scale (Appendix A3.2). Pilot test meal analysis questions 5, 6, 7, and 8 became main study questions 6, 7, 8, and 9. The participants showed better adherence to the completion of the qualitative section of the test meal analysis in the pilot study than in the main study.

The pilot study test meal analysis and digestive symptoms rating scale results were initially analyzed parametrically producing integers between the ranks. Participants were only able to respond to the scale as whole integers and as such in the main study only the whole number ranks were used to investigate differences between the test meal conditions. Pilot study digestive symptom rating scale results prompted modifications to the main study digestive symptom rating scale to reduce participant and researcher burden (i.e. fewer collection points), and produce results that more accurately represented the participants' experienced digestive symptoms. The main study digestive symptoms rating scale assessed 5 digestive symptoms (fullness, bloating, nausea, abdominal cramping, and hunger) at the following 9 time points: -140 (baseline), -120, -105, -90, -60, 0, 45, 90, and 105 minutes.

Quantitative measurements of repeat sprint distances were obtained in the pilot study from the digital output of the treadmill; however, a substantial amount of measurement error was noted with reliance on the digital output. A new protocol was therefore established to measure the distance covered in the main study repeated sprint tests, whereby the treadmill belt length was measured and permanently marked to accurately track rotations and calculate distance covered. The number of belt rotations for each sprint were then quantified manually with a handheld counter, and multiplied by the length of the belt. This allowed the distance covered (meters) to be measured with improved accuracy to the nearest meter rather than to the nearest 16^{th} meter.

The pilot study post-prandial period was three hours in duration; however, when the levels of serial blood glucose were assessed in the participants (via finger prick blood glucose analysis, as assessed by Little et al., 2008), a three hour post-prandial period was found to generate identical blood glucose levels immediately prior to testing across all meal conditions. Upon analysis of the blood glucose curve, the most advantageous postprandial assessment point for the low glycemic meal was determined to be two hours after meal completion. An additional factor of importance considered when reducing the postprandial time from three hours to two hours was the inability of the subjects to consume the entire pre-exercise meal. As previously mentioned, the ideal available carbohydrate provision of 2.0-3.0 $g \cdot kg^{-1}$ 3-4 hours before exercise is reduced to 1.0-2.0 $g \cdot kg^{-1}$ when delivered 1-2 hours before exercise (Kreider et al., 2010; Rodriguez et al., 2009). As the pilot study participants could only consume a portion of the meal designed to deliver 2.0 g carbohydrate$\cdot kg^{-1}$ the main study therefore employed a briefer two hour post-prandial period while maintaining recommendations for carbohydrate consumption and digestion time prior to exercise as per the Institute of Medicine (2005).

Of the three pilot study conditions, 2 fed and 1 fasted, the two fed conditions were matched for macronutrient profile and differed in glycemic index, but did not allow for the investigation of the influence of pre-exercise meal protein content on physiological conditions pertaining to improved exercise performance. In the main study a third high GI low protein pre-exercise meal was added to enable comparisons between high protein and low protein pre-exercise meals on nutritional and metabolic requirements for optimal performance. This new fed condition (potato), which consisted of instant mashed potatoes, white bread and ketchup, matched the other meals for caloric content, reduced protein content via egg white omission, and increased carbohydrate amounts with additional white bread and potatoes.

In conclusion, pilot study findings enabled the generation of a main study design and protocol with improved assessment tools and methodology for accurate and reliable data collection and interpretation. Alterations in pre-exercise meal size may lead to improved consumption amounts and hence improved performance outcomes in the simulated soccer trial. Accurate assessment of the participants' sensory perceptions of the pre-exercise meals and digestive symptoms resultant of the pre-exercise meals will enable detailed analysis of the applicability, acceptability and palatability of lentils as a pre-exercise meal for athletes of high-intensity intermittent exercise.

CHAPTER 5: MAIN STUDY

5.1. Methodology

5.1.1. Participants

Sixteen male varsity or club soccer players or varsity track and field middle distance runners participated (age 22.8 ± 3.2 y; maximal oxygen uptake [VO_{2peak}], 55.4 ± 4.3 $mL \cdot kg^{-1} \cdot min^{-1}$; peak treadmill speed [$V_{max}$], 17.9 ± 1.7 $km \cdot h^{-1}$). The data from the 13 participants who completed all aspects of the research study were used for analyses. None of the participants had any known food allergies or digestive conditions that could have interfered with the research study. The study procedures and protocol were approved by the Biomedical Research Ethics Board of the University of Saskatchewan, and participants completed a written consent form before any measurements were taken (Appendix A2.1).

5.1.2. Experimental Design

The main study experimental design required the participants to complete six visits to the laboratory. Preliminary procedures, as described thoroughly in 4.1, performed during the first two visits to the laboratory determined the participant's aerobic capacity and maximum speed at their aerobic capacity (Harling et al., 2003), and familiarized the participants with the treadmill and exercise protocol for the experimental trials. Specific details regarding preliminary tests, familiarization trial, and simulated soccer trial protocol are available from Little et al., (2008), and Little et al., (2010). The second visit had participants participate in a full treadmill based soccer-trial to familiarize them with speeds and procedures (Drust, et al., 2000). The simulation was administered in standardized 15-minute blocks consisting of 6 walking (75 s), 6 jogging (40 s), 3 running (20 s), and 8 sprint (12 s) intervals (Table 4.4). The first half of the trial included three identical 15-minute blocks and the second half included two identical 15-minute blocks plus a repeated sprint test in the last 15 minutes. The repeated sprint test consisted of five participant-guided 1-minute sprints, each separated by 2 minutes and 30 seconds of recovery as described in section 4.1. Experimental trials were carried out over four weekly visits each employing a different randomized experimental meal condition. The participants were blind to the research study hypotheses, and were not informed which experimental condition they were to experience before testing. One experimental trial employed a fasted control condition, the remaining three fed trials employed a low GI – high protein (GI = ~29) lentil pre-exercise meal, a high GI – high protein (GI = ~76) potato & egg white pre-exercise meal delivering 1.5 g total carbohydrate per kilogram body weight, and a high GI-low protein (GI = ~76) potato pre-exercise meal delivering 1.9 g total carbohydrate per kilogram body weight (GI values from Foster-Powell et al., 2002). The greater carbohydrate content of this final condition was to match the other two conditions for caloric content since the other two conditions had extra protein. All four experimental conditions included a 2 hour post-prandial period and subsequent simulated treadmill-based soccer trial. Performance during each experimental condition was assessed with a repeated sprint test in the last 15 minutes of the simulated soccer trial. A single-blind, randomized counter-balanced design was employed as described in 4.1.2. At various time points throughout the post-prandial and exercise periods participants rated sensory perceptions of the pre-exercise meals and post-prandial gastrointestinal digestive symptom severity. Following the experimental trials the participants were asked to complete a questionnaire investigating nutrition knowledge and beliefs and barriers toward lentils and pulse-based meals.

5.1.2.1. Details of Experimental Meal Conditions

The main study consisted of four experimental conditions: two fed experimental pre-exercise meal conditions were designed to provide 1.5 grams of total carbohydrate per kilogram body weight, one fed experimental condition designed to provide 1.9 grams total carbohydrate per kilogram body weight, and one un-fed fasted control condition were administered in a randomized counter balanced design.

Table 5.1. Pre-exercise energy and macronutrient content (based on a 70 kg participant).			
	Low GI-high protein (lentils)	**High GI-high protein**	**High GI-low protein**
Energy (kcal)	~632	~632	~632
Carbohydrate (g)	105.0	105.1	131.2
Protein (g)	44.3	44.0	18.0
Fat (g)	3.9	3.9	3.9
Glycemic Index (GI)	~26	~76	~76

A control condition (no meal) was also employed. GI values for individual foods are from Foster-Powell et al. (2002). GI values for the high GI meals were calculated using the mixed meal method from Wolever and Jenkins (1986).

The three isoenergetic pre-exercise meal conditions consisted of a low GI high protein lentil meal, a high GI high protein instant mashed potato, white bread, and egg white meal, and a high GI low protein instant mashed potato and white bread meal (Table 5.1).

The meals were individualized according to the body weight of each participant in order to provide the designed amount of total carbohydrate. The pre-exercise meal components are the same as those employed in the pilot study, other than the addition of white bread to the high GI potato meals, and are thoroughly described above in section 4.1.2.1, and depicted in Table 5.2 below.

Table 5.2: Macronutrient composition of component test foods.						
Nutrient name	**Protein (g)**	**Fat (g)**	**Carbohydrate (g)**	**Energy (kcal)**	**Fibre (g)**	**Sugars (g)**
Lentil, whole, red	24.8	1.0	59.1	302	14.2	1.8
Tomato, ketchup	1.7	0.5	25.8	100	1.7	22.8
RTS Seasoned Mashed Potatoes	1.8	2.1	14.9	98	1.6	0.8
Egg, white, chicken, raw	10.2	0.0	0.8	47	0	0.7
Bread, white, commercial	7.6	3.3	50.6	266	2.4	4.3

Values for food items were obtained online from the Canadian Nutrient File and are per 100 g of edible portion. McCain RTS (Ready to Serve) Seasoned Instant Mashed Potato values were obtained from McCain Canada. Carbohydrate values includes fibre amounts

The raw amounts of each component required to produce a pre-exercise meal providing 1.5 grams total carbohydrate are listed in Table 5.3 below. The low GI lentil meal and high GI potato & egg meal were designed to provide 1.5 g total carbohydrate per kilogram body weight and were matched for macronutrients (see Table 5.1).

Table 5.3: Pre-exercise meal component amounts for designed pre-exercise meals.

Meal Components	Lentil Meal	Potato Meal	Potato & Egg Meal
Lentil, whole, red, dry ($g \cdot kg^{-1}$)	1.8		
Tomato, ketchup ($g \cdot kg^{-1}$)		0.7	0.7
Instant Potato Flakes, dry ($g \cdot kg^{-1}$)		1.3	1.0
Egg, white, chicken, raw ($g \cdot kg^{-1}$)			3.9
Bread, white, commercial ($g \cdot kg^{-1}$)		1.9	1.5

Values expressed as required raw amounts to produce total carbohydrate amounts of 1.5 $g \cdot kg^{-1}$ in the pre-exercise meal design. All values are expressed per kilogram body weight. Carbohydrate values include fibre amounts.

The low GI high protein lentil meal and the high GI high protein potato meal both delivered 1.5 g total carbohydrate, 0.63 g protein, and 0.05 g fat, all per kilogram body weight. The high GI low protein potato meal contained more carbohydrate content, 1.9 g total carbohydrate per kilogram body weight, reduced protein content of 0.26 g per kilogram bodyweight, and similar fat content, to ensure that the meal was isoenergetic with the other pre-exercise meal conditions.

5.1.2.2. Details of Sensory Meal Analysis

A modified version of the pilot study test meal analysis, described in the pilot study above (4.1), containing 9 items evaluated the participants' perceptions using quantitative fixed point rating scales of 3 and 5 ranks and a qualitative test meal comment portion (Aiken, 1996; Clason & Dormondy, 1994). The items of the analysis are located in Table 5.4 below, and were designed to investigate participant sensory perceptions of meal appetite, acceptability, and palatability. Each question was dedicated a specific rating scale to enable accurate assessment of the sensory perceptions investigated: questions 1, 2, 3, 6, 7, and 8 provided 5 fixed point ranks for assessment and questions 4, 5, and 9 assessed perceptions with 3 point ranks: yes, no, and I don't know (Table 5.4). The complete test meal analysis is available in Appendix A3.2.

Table 5.4.: Main study test meal sensory analysis content.		
Item		**No. of Ranks**
1	How did the meal look?	5
2	What did you think about the size?	5
3	How did you find the ease of consuming the entire meal? If you had difficulties consuming the entire portion can you describe why?	5
4	Did the meal have an aroma?	3
5	Is the aroma of the meal appealing?	3
6	What is the texture of the meal?	5
7	How did you find the ease of chewing and swallowing the meal?	5
8	The flavour of the meal was?	5
9	Do you feel you will be able to exercise with ease at the beginning of the testing?	3

Nine items investigating the palatability of the pre-exercise meals and the number of scale ranks for each item are listed above. The examination tool is located in Appendix A3.2. Items interpreted from Sorensen et al., 2003.

5.1.2.3. Details of Digestive Symptoms Rating Scale

Research participants' symptoms of gastrointestinal distress were assessed with an adjusted version of the digestive symptoms rating scale described in the pilot study above (see section 4.1). Modifications of the preliminary rating scale generated a more succinct tool assessing five digestive symptoms at 10 time points throughout testing (Appendix A3.1). The scale employed a fixed point scale with five ranks to assess digestive symptom severity: 0 = no symptoms, 1 = mild symptoms, 2 = moderate symptoms, 3 = moderately severe symptoms and 4 = severe symptoms. Digestive symptoms of fullness, bloating, nausea, abdominal cramping and hunger have typically been used for gastrointestinal disturbance assessments in sport and medical jurisdictions and were chosen for adequate symptom assessment of the delivered pre-exercise meals (Deibert et al., 2005; Brouns, 1991; Brown et al., 1994; Bi & Triadafilopoulos, 2003; Collings et al., 2003; Gisolfi, 2000; Peters et al., 1999; van Niewenhoven et al., 2004). The participants were asked to complete the scale at ten time points during testing: a baseline measurement was collected upon arrival to the laboratory, and 9 subsequent assessments were completed at -120, -105, -90, -60, -30, and 0 minutes before exercise testing, and 45, 90, and 105 minutes after exercise testing had commenced. The rating scale delivered to the participants is available in Appendix A3.1.

5.1.2.4. Details of 24 hour Dietary and Activity Records

As in the pilot study, possible activity or diet-induced metabolic or physiological variability was minimized as participants completed a 24-hour diet record and 24 physical activity record prior to experimental testing to be mimicked for all four experimental conditions. The dietary intake record used for the main study was unaltered from the pilot study and details are described above in section 4.1.2 (Appendix A3.3). At the end of the second laboratory visit the participants were provided the intake record and instructed on proper completion. The participants were to complete the dietary record in the 24 hours prior to the first experimental testing day; they were also informed the dietary record collected before the first trial would be maintained in the 24 hours prior to each trial. At the same time, a 24 hour physical activity record (as described in section 5.1.2) was given to the participants to track training (intensity, time, and type) prior to the first experiment day (Appendix A3.4). A trained nutrition researcher reviewed record accuracy with each participant during the post-prandial period of each trial. Diet records were copied and returned to participants with instruction to consume a similar diet for 24 hours prior to the subsequent experimental trials. Dietary adherence was assessed on each testing day; if the participants failed to adhere to the dietary record presented on the first trial deviations would be noted and recorded for later analyses. The participants would be instructed to return back to the initial dietary record prior to the next experimental trial.

The dietary intake records were used to generate total daily energy and carbohydrate amounts for each participant.

5.1.2.5. Details of Exercise Testing

Preliminary and exercise testing protocols utilized in the main study were unaltered from those employed in the pilot study above. Details regarding the design and procedures of the preliminary tests, familiarization trial, simulated soccer trial, and specificities of the software, treadmill and individualized protocols can be obtained from Little et al., (2008), and Little et al., (2010).

5.1.2.6. Details of Questionnaire

A questionnaire was developed to evaluate each participant's knowledge of nutrition and identify beliefs and barriers toward pulse-based meals (Appendix A3.5). This questionnaire was adapted from previously generated questionnaires: one investigated beliefs and barriers towards plant-based meals and the second investigating general nutrition knowledge (Lea, 2006; Zawila et al., 2003). The first examination tool, from Lea et al., (2006) was chosen at the time of this research study as few questionnaires investigating cognitive concepts regarding consumption of lentils or pulse crops were available; as such, the plant-based assessment was modified to assess pulse-based meals and or lentils. The questionnaire adequately addressed attitudes, beliefs, barriers and other concepts that were believed to influence plant-based consumption. The definition of pulses and pulse crops was provided at the beginning of the questionnaire, and a total of 22 barriers-related questions and 17 beliefs-related questions were included. The beliefs and barriers portion of the questionnaire employed a fixed-5-point scale (0= strongly disagree, 1 = disagree, 2 = not sure, 3 = agree, 4 = strongly agree) to quantify the participant's cognitive psychosocial concepts towards pulse-based meals and lentils. The second questionnaire employed had previously been applied to young varsity athlete populations and as such seemed appropriate for this research study. In the work of Zawila et al., nutritional knowledge was assessed using a 76-item multiple choice questionnaire (Zawila et al., 2003). Demographics such as age, gender, household information, student/employment status were assessed in addition to several health related questions (Appendix A3.5). The generated questionnaire was initially employed on the participants of this research study, but was also administered in a similar research study with a greater participant number (Bennett, Chilibeck, Barss, Vatanparast, Vandenberg, & Zello, 2012). Questionnaire results remained anonymous.

5.1.3. Experimental Protocol

Fasted participants (minimum 10 h) arrived at the laboratory between 6:00 and 7:00 am, and baseline physiological, sensory and gastrointestinal symptom measurements were taken. After baseline value collection, participants were escorted to the meal delivery room to consume the provided experimental meal or continue fasting. Participants were told to consume the entire meal portion to ensure isocaloric intake between experimental meal conditions. If the meal was not completely consumed, the remaining meal conditions were scaled to match the amount consumed in the first delivered meal condition. Any uneaten portions were weighed to the nearest tenth of a gram, recorded and discarded. Throughout consumption and post-prandial periods the participants were asked to complete a post-prandial digestive symptom rating scale to assess gastrointestinal digestive symptom severity, and a sensory test meal analysis to assess perceptions of pre-exercise meal acceptability. The volume of water consumed throughout testing was recorded, and the participant was informed that the volume consumed would have to be matched in subsequent trials. As post-prandial time approached 0, or the beginning of the exercise testing, the participant was asked to prepare for the exercise and return to the laboratory.

Immediately prior to exercise, physiological and sensory assessments were again performed and the participant began a short warm up on the treadmill. Exercise testing began promptly at time zero and sensory and physiological parameters were assessed between all 15 min blocks. After 45 minutes, participants were allowed to rest 15 minutes and then resumed the latter 45 minutes of the tests: 2 fifteen minute blocks and 1 block of repeated sprint testing. After the completion of the test, the participant was allowed to cool down. The participants were reminded to follow the 24 hour dietary record and 24 hour physical activity record as best they could the day prior to the next experimental testing day.

5.1.3.1. Pre-exercise Meal Administration and Analysis

All pre-exercise test meals were prepared immediately prior to participant arrival on each testing day according to the randomized delivery of each experimental meal. When participants were to consume the lentil meal, the dry weight (grams) of lentils required to provide 1.5 grams total carbohydrate, 180 grams dry lentils for a 70 kg participant, would be measured and transferred into a sieve. The lentils were then rinsed with cold water and placed into a large sauce pan. To the lentils water was added at 3 parts water to 1 part lentil. The lentils were cooked until soft and a pinch of salt was added at the end of the cooking process to prevent seed toughness and improve meal flavour. The lentils were then placed in a storage container and transported to the meal delivery room for the participant to consume. Tomato paste was offered, in a small negligible amount 15-30 g, along with the lentils if participants required the addition to consume the delivered portion. If the potato meal was required on a testing day, meal preparation would begin with the measurement of the dry grams of instant mashed potato flakes required for each participant into a large heat resistant vessel. According to manufacturer's directions the appropriate amount of boiling water was added to the flakes and the mixture was whipped with a hand blender until smooth. The white bread was weighed, according to the participant's pre-designed amount, in a tarred vessel and covered until meal consumption. The ketchup was also weighed in a tarred vessel and delivered alongside the potatoes and bread if required for improved palatability. The potato & egg meal was prepared as the potato meal above with the addition of egg whites. The egg whites were weighed in a tarred vessel and cooked in a microwave oven until light and fluffy. All meal components were reweighed to the nearest tenth of a gram. All potato meal components were delivered in individual vessels to ensure macronutrient balance equivalent to that of the lentil meal was consumed. Any uneaten portions were weighed to the nearest tenth of a gram, recorded and discarded. Consumed portions were divided by the prepared amount and individual participant consumption amounts were expressed as a percentage of designed delivered pre-exercise meal. If participants were unable to consume the entire delivered portion of the pre-exercise meal, subsequent meals would be delivered to match the amount consumed in the first fed experimental condition. This was carried out to ensure the participants were not able to consume more energy or carbohydrate in the remaining trials than was consumed in the first.

5.1.3.2. Test Meal Sensory Analysis Administration and Analysis

Following consumption of each of the three fed experimental meals the participants were asked to complete the test meal analysis investigating their sensory perceptions of the delivered pre-exercise meal. The participants were allowed to complete the analysis in the meal consumption room and were instructed to complete the analyses to the best of their ability by applying a check or mark on the rank that best described their perception and providing written feedback if desired in the allotted spaced below each question. After completion, the research assistant gathered the analysis and the participants were allowed to remain relatively inactive for the remainder of the post-prandial period. Each participant completed three test meal analyses and the results were grouped by condition and entered into statistical software. Average ranks, as non-parametric whole integers were used to compare sensory perceptions between the fed meals. No test meal analysis was administered in the unfed control condition.

5.1.3.3. Digestive Symptoms Rating Scale Administration and Analysis

Upon arrival to the laboratory on each experimental testing day participants were asked to complete the first of ten assessments of their gastrointestinal symptom severity. The participants were instructed how to properly complete the scale with an example provided regarding hunger: if the participant did not feel hungry at all then a rank of 0 was applied, as symptom severity approached painful pangs of hunger in the gut/stomach the participant was instructed to increase the rating to a maximum of 4 on the scale or severe symptoms. During meal consumption and throughout the post-prandial period (assessment time-points 2-7) the participants were prompted to complete the questionnaire at the appropriate time, and marked their scores. During exercise testing measurements (at 45, 90, and 105 minutes) the participants were asked by the research technician to verbally indicate (0-4) the severity of each of the five symptoms. The research assistant marked the participant's symptom severity and following exercise collected the rating scales. Each participant completed four symptom rating scales, the results were grouped by experimental condition and rank averages were calculated for comparisons between experimental conditions at each time point.

5.1.3.4. 24 h Dietary and Activity Records Administration and Analysis

Following the familiarization trial, participants were given a 24 hour food intake form and instructed to list liquid or solid sources of calories consumed as well as respective volumes and quantities in the 24 hours prior to their arrival to the laboratory for the first experimental trial (Appendix A3.3). At the same time, after familiarization, a 24 hour physical activity record was also provided to track training (intensity, time, and type) prior to the first experiment day (Appendix A3.4). Participants were required to present the completed dietary and physical activity records upon arrival to the laboratory on the first experimental testing day. After meal consumption in the first experimental trial a trained research technician verified the accuracy of the food and activity record with the participant: reviewing portion sizes, volumes, and all possible sources of energy intake for consistent determination of macronutrient and energy intake. The forms were copied and returned to the participants along with instructions to replicate the dietary intake and physical activities the day prior to the next experimental trial. If the participant's dietary pattern was completely different, the changes in dietary consumption were noted and the participant was asked to return the initial dietary record for the subsequent trials. Any observed changes in the dietary intake record between trials was recorded and compensated for in the calculation of total energy consumed. The information collected was entered into Diet Analysis $^{+}$ (version 8.0, Wadsworth/Nelson Education Ltd., Scarborough, ON) to calculate 24 hour total energy ($kcal \cdot kg^{-1} \cdot day^{-1}$) and total carbohydrate intake ($kcal \cdot kg^{-1} \cdot day^{-1}$) for each participant.

5.1.3.5. Exercise Testing Collection and Analysis

To assess the effects of energy and carbohydrate consumption on exercise performance, an overall score for exercise performance, the Overall Performance Score (OPS), was generated for each participant. Exercise performance, as determined from five 1-minute repeated sprint tests carried out in the last 15 minutes of exercise with 2 minutes 30 seconds rest between sprints, was measured by the distance (m) covered. Distance covered in each of five sprints ($SD_{X1\text{-}5}$) was calculated by the product number of revolutions of the treadmill belt and the length (meters) of the belt (details of the sprint test can be found from Little et al., 2010). The sum of distances covered ($SD_{X1\text{-}5}$) in the five 1-minute sprints produced individual participant total sprint distances ($TSD_{W\text{-}Z}$) for each experimental condition (see Equation 5.1).

(Equation 5.1) $TSD_{X(\text{meters})} = SD_{X1} + SD_{X2} + SD_{X3} + SD_{X4} + SD_{X5}$,

where X = the experimental condition assessed, and *1* through *5* are the individual distances for each one of five sprint tests (meters), SD = sprint distance, TSD = total sprint distance for one experimental trail. Four TSD values were calculated for each participant.

Four total sprint distance scores ($TSD_{W\text{-}Z}$) were generated for each of the participants: control (*w*), lentil (*x*), potato (*y*), and potato & egg (*z*). An overall performance score (m) was calculated for each research participant and was obtained by combining the total sprint distance ($TSD_{W\text{-}Z}$) covered in each experimental trial and then calculating the average distance covered across all four experimental trials (Equation 5.2).

(Equation 5.2) $OPS\ (m) = (TSD_W + TSD_X + TSD_Y + TSD_Z)/\ 4$,

where OPS (m) = overall performance score for each participant, TSD (m) = total sprint distance for each condition *w* (control), *x* (lentil), *y* (potato), and *z* (potato & egg).

5.1.3.6. Energy and Carbohydrate Consumption and Performance

During the post-prandial period the twenty-four hour dietary record for each participant was reviewed between the participant and the researcher to ensure accuracy of weight and volume quantifications during the post-prandial period and the compiled information was then entered into dietary analysis software [Diet Analysis$^+$ V.8.0, Wadsworth/Nelson Education Ltd., Scarborough, ON]. Total grams of carbohydrate ($g \cdot kg^{-1}$) and total kilocalories ($kcal \cdot kg^{-1}$) consumed in the previous 24 hours were calculated and expressed relative to kilograms body weight. Values from the analysis of the 24 h dietary record were designated as the total energy and carbohydrate intake variables for the fasted experimental control condition.

After completion of all experimental trials, individual pre-exercise meal energy and carbohydrate intake ($kcal \cdot kg^{-1}$, $g \cdot kg^{-1}$) were calculated and averaged to generate two variables from pre-exercise meal consumption for each participant. Specifically, the consumed energy and carbohydrate amounts from each participant's lentil, potato, and potato & egg meals were determined and averaged to generate two single intake variables for each participant: meal energy ($kcal \cdot kg^{-1}$) and meal carbohydrate ($g \cdot kg^{-1}$). Total energy and total carbohydrate per day (24 h + pre-meal) were calculated per participant for each fed condition as the sum of the 24 h dietary record values plus the pre-exercise meal values, and then averaged.

Four average intake variables were generated per participant: meal energy ($kcal \cdot kg^{-1}$), meal carbohydrate ($g \cdot kg^{-1}$), total energy (24 h + pre-exercise meal) ($kcal \cdot kg^{-1} \cdot day^{-1}$), and total carbohydrate (24 h + pre-exercise meal) ($g \cdot kg^{-1} \cdot day^{-1}$). The appropriate evaluation of the effects of the four variables of energy or carbohydrate intake on exercise performance, as OPS (m), was executed by comparing two groups, high and low intake, within each of the four variables versus overall performance score (m) to identify effect of intake on exercise performance. For example, individual participants' total energy intakes were arranged by decreasing value and a mode was determined: the high energy group consisted of data above the mode and the low energy group consisted of data that fell below the mode. If a value fell on the mode the range of the data set was determined, if the mode was above the range the value fell into the high energy group, if the value was less than the range then it fell into the low energy group.

Employing the variables explained above, the effects of energy and carbohydrate consumption on exercise performance were investigated in two ways. Firstly, the effects of the pre-exercise meal intake alone were assessed by comparing the effects of meal energy ($kcal \cdot kg^{-1}$) and meal carbohydrate ($g \cdot kg^{-1}$) on exercise performance (OPS (m)). Secondly, the effects of the cumulative intake from the 24 hour dietary record and pre-exercise meal were investigated, and the same comparisons performed. The effects of total energy intake ($kcal \cdot kg^{-1}$) and total carbohydrate intake ($g \cdot kg^{-1}$) from the combined pre-exercise meal and 24 h dietary intake on OPS (m) were assessed between high and low intake groups. Effects on overall performance score of total energy and total carbohydrate intakes to meal energy and carbohydrate intakes were compared to determine if the provision of pre-exercise energy is more influential than energy provision from the previous day.

5.1.3.7. Questionnaire Administration and Analysis

After completion of all four experimental trials the participants were provided a questionnaire investigating their beliefs and barriers towards pulse-based meals and general nutrition knowledge. The preliminary version of the questionnaire was completed by 12 of the main study participants. However, since the preliminary draft had not been tested for reliability and validity, the draft was revised, and questions were added from validated questionnaires previously utilized to assess dietary beliefs and behaviours, as well as a section for general nutritional knowledge. After the completion of the main study, all participants were therefore asked to sign new consent forms (Appendix A2.2) and complete the revised questionnaire. The questionnaire was delivered to all of the initial recruits for the study, even if they had withdrawn due to time constraints or physical limitations. The participants were instructed to complete the questionnaire to their best ability, and were not advised on any components. Participants were also provided the option to complete the questionnaire in more than one sitting to reduce respondent apathy. The participants were allowed to return the questionnaire to the research assistant after completion, or were provided a post-marked envelope to return the questionnaire by mail. The participants were instructed to complete the questionnaire to the best of their ability and return it to the researcher.

5.1.4. Statistics

Average pre-exercise meal consumption percentages and average sprint distances were analyzed for difference with a one-factor (meal condition) analysis of variance (ANOVA) with Tukey's post hoc tests when differences were found. Significant differences between total sprint distances (TSD (m)) of the experimental conditions were analyzed with an orthogonal contrast within ANOVA. Statistical analysis of the repeated sprint tests in the last 15 minute block of testing was performed by repeated measures ANOVA: 4 (meal condition) × 5 (sprint) in the main study , and when significance was detected Bonferonni post hoc tests were employed to isolate specific interactions. The 9 items of the sensory test meal analysis were assessed employing two methods. The 5-point Likert scale portion of the sensory test meal analysis was statistically analyzed using one-factor (meal condition) repeated measures ANOVA. The comment section of the assessment tool evaluated the participant's sensory perceptions by meal condition. The post-prandial digestive symptoms rating scale was analyzed with a two-factor (meal condition × time) ANOVA with repeated measures on both factors. The effects of high and low energy and carbohydrate intake manipulation on overall performance score (m) (dependent variable) were investigated with a series of independent univariate ANOVAs: total energy ($kcal \cdot kg^{-1} \cdot day^{-1}$), total carbohydrate ($g \cdot kg^{-1} \cdot day^{-1}$), meal energy ($kcal \cdot kg^{-1}$), and meal carbohydrate ($g \cdot kg^{-1}$). Post hoc analysis was not required. Correlations between overall performance score (m) and each of the four aforementioned variables were assessed with Pearson's Correlations Coefficient (r). All results are expressed as means ± standard deviation. Statistical analyses were performed on SPSS version 17.0, and significance was accepted at $p<0.05$.

5.1.4.1. Questionnaire Analysis

The data collected from the questionnaire were imputed into SPSS 17.0 for analyses. The barriers and beliefs section was compressed to three possible outcomes for each question: the first contained the positive responses (strongly agree, agree), the second contained the neutral response, and the third contained the negative responses (disagree, strongly disagree). The nutritional knowledge questions were assessed to determine an overall general nutrition knowledge score. Within the nutritional knowledge questions several themes or subgroups were created to investigate specific knowledge scores such as subgroup scores for specific athlete nutrition, and subgroup such as macronutrient, hydration, health benefit and functional food knowledge (Lea, 2006). Demographic information descriptive statistics were tabulated in order to provide correlations and feedback regarding the relationship between some of the demographic data and cognitive concepts of beliefs and barriers towards lentils and pulse-based crops. Relationships between the cognitive concepts of attitudes and beliefs and variables of demographics, pulse and lentil consumption, and nutrition knowledge investigated in the questionnaire were determined with correlations using Pearson's rho 2-tailed test. The relationships of nutrition knowledge score and athlete specific nutrition knowledge score to pulse and lentil consumption per week were also investigated using bivariate correlation. Correlations were considered significant if $p < 0.05$.

5.2. Results

5.2.1. Consumption Amounts

Table 5.5 provides the percentage of the delivered meals that were consumed by each participant, as well as the average group consumption for each meal. No significant differences were detected in consumed amounts between meals ($p < 0.05$), with an average of 79.5 ± 1.8%

of the delivered meal consumed. Consumption amounts as meal energy ($kcal \cdot kg^{-1}$), meal carbohydrate ($g \cdot kg^{-1}$) and the consumed percentage for each participant in each meal are shown in Table 5.5. Meal energy between the conditions was significantly different ($p < 0.001$; $F = 8.284$), with Tukey's post hoc analysis identifying significant differences between the lentil and potato & egg meal (7.2 ± 1.6 vs. 9.3 ± 1.8, respectively), and between the lentil meal and the potato meal (7.2 ± 1.6 vs. 9.6 ± 1.5, respectively) $p < 0.01$. No significant difference was observed between the potato and potato & egg meals for total energy intake ($kcal \cdot kg^{-1}$). Meal condition had a significant effect on carbohydrate consumption ($p < 0.001$, $F = 29.250$), with Tukey's post hoc tests identifying paired differences between the lentil and potato & egg meals (0.9 ± 0.2 vs. 1.2 ± 0.2, respectively), lentil and potato meals (0.9 ± 0.2 vs. 1.5 ± 0.2, respectively), and the potato & egg and potato meals (7.2 ± 1.6 vs. 9.6 ± 1.5, respectively), $p < 0.01$ for all three pairs.

Table 5.5: Pre-exercise meal data

	Meal Consumption Variables								
Participant	**Energy ($kcal \cdot kg^{-1}$)**			**Total Carbohydrate ($g \cdot kg^{-1}$)**			**Delivered Amount Consumed (%)**		
	L	**P&E**	**P**	**L**	**P&E**	**P**	**L**	**P&E**	**P**
1	8.6	10.9	10.0	1.2	1.4	1.5	91.1	90.2	89.6
2	4.0	6.2	9.3	0.5	0.9	1.5	44.5	44.2	69.5
3	8.6	10.9	7.9	1.2	1.4	1.3	90.0	90.9	54.2
4	9.1	10.7	10.7	1.2	1.3	1.6	97.4	90.0	82.7
5	9.3	11.3	11.2	1.2	1.5	1.8	100.0	97.3	100.0
6	7.1	10.3	10.2	0.9	1.4	1.6	99.6	73.8	77.4
7	6.3	10.7	9.8	0.8	1.3	1.5	71.6	92.7	64.3
8	8.1	10.9	10.9	1.1	1.5	1.6	87.2	100.0	92.1
9	5.9	7.5	9.3	0.8	0.9	1.4	66.2	69.5	77.2
10	7.0	9.0	11.6	0.9	1.2	1.7	76.8	99.2	94.1
11	5.4	7.0	8.2	0.7	0.9	1.3	61.2	88.2	100.0
12	7.3	7.4	6.5	0.9	1.1	1.0	80.8	49.3	49.6
13	6.7	8.3	8.7	0.8	1.1	1.3	72.1	68.0	58.4
Mean	7.2	9.3	9.6	0.9	1.2	1.5	79.9	81.0	77.6
SD	1.6	1.8	1.5	0.2	0.2	0.2	16.6	18.5	17.3

Pre-exercise meal consumption amounts: variables of energy and carbohydrate amounts, expressed relative to body weight (kg), and meal consumption as a percentage (%) of meal designed to deliver 1.5 g $CHO \cdot kg^{-1}$ body weight for each participant across all meal conditions. Meal conditions abbreviated as L = lentil, P & E = potato & egg, and P = potato.

5.2.2. Sensory Perceptions of Pre-exercise Meals

5.2.2.1. Visual Perceptions

The first question investigated the participant's visual perceptions of the pre-exercise meals (Table 5.5). There was a significant main effect of meal condition on the appearance of the meal assessed in question 1 ($p < 0.01$, $F=9.278$). Post-hoc comparisons identified a greater tolerance of the meal's appearance in the potato condition when compared to the lentil and potato & egg meals ($p < 0.01$, potato=2.9; lentil=1.5; potato & egg=1.9). No statistically significant difference was observed between the two high protein conditions ($p < 0.01$).The lentil meal was rated as "not appealing" by 64% of respondents, while the potato and potato & egg meals were rated as such by 0% and 44% of participants, respectively. The percentages of responses in the five ranks for each meal condition are shown in Table 5.6. The most positive rank of "appealing" visual perception was only given 20% of responses in the potato condition. On average, the potato & egg and lentil meals rated between "not appealing" and "somewhat appealing" while the potato meal on average was ranked as "neutral". High protein meal consumption generated the greatest percentages of "not appealing" visual perceptions.

Table 5.6: Rating percentages of visual perceptions

How did the meal look?	**Not appealing**	**Somewhat Appealing**	**Neutral**	**Appealing**	**Very Appealing**
Lentil	64%	27%	9%	0%	0%
Potato*	0%	30%	50%	20%	0%
Potato & Egg	44%	22%	33%	0%	0%

Responses for question 1 from the test meal analysis are expressed in percentages of responses for each option on the rating scale. * - a significant difference between the meal conditions was observed as the potato meal was more positively rated than the lentil or potato & egg meals.

5.2.2.2. Taste Perceptions

The eighth question assessed participants' perceptions of meal flavour (Table 5.7). A main effect of meal condition on meal flavour was identified ($p < 0.05$), with post hoc tests determining a difference between the lentil (64% not appealing flavour) and potato (0% not appealing flavour) meals ($p<0.05$). No other differences in pair-wise comparisons were observed. Only the lentil and potato & egg conditions elicited responses in the most negative rank, "not appealing" with regards to flavour. The majority of participants rated the flavour of the high glycemic meals as neutral. The sole "appealing" responses were observed in the potato meal, and the potato meal was perceived to have a more favourable flavour than the lentil meal on average; however, no significant differences were observed between the ratings of flavour in the high protein conditions. On average the potato meal was perceived to have a more favourable flavour than the lentil meal, but there was no difference between the ratings of flavour between the high protein conditions.

Table 5.7: Rating percentages of flavour perceptions

The flavour of the meal was?	**Not appealing**	**Somewhat Appealing**	**Neutral**	**Appealing**	**Very Appealing**
Lentil	64%	9%	27%	0%	0%
Potato*	0%	22%	66%	11%	0%
Potato & Egg	25%	0%	75%	0%	0%

Responses for question 8 from the test meal analysis are expressed in percentages of responses for each option on the rating scale. * - a significant difference between the meal conditions was observed as the potato meal was more positively rated for flavour than the lentil meal.

5.2.2.3. Size and Palatability Perceptions

Participants' response percentages regarding meal size are illustrated in the following table (5.8). No statistically significant differences between the meal conditions were identified. None of the meals produced rankings of size lower than "average". The most frequently answered score was "large" (4th rank): 55% lentil, 60% potato, and 67% potato & egg condition. Participants only rated the lentil meal as "cumbersome" (5th rating).

Table 5.8: Rating percentages of size perceptions

What did you think about the size?	**Very Small**	**Small**	**Average**	**Large**	**Cumbersome**
Lentil	0%	0%	18%	55%	27%
Potato	0%	0%	40%	60%	0%
Potato & Egg	0%	0%	33%	66%	0%

Responses for question 2 from the test meal analysis are expressed in percentages of responses for each option on the rating scale.

The majority of lentil and potato & egg participants' responses gathered in the "not easy" to consume the meal entirely. No significant differences were observed in ease of consumption perceptions between the meal conditions. The potato meal elicited responses across the entire palatability ranking spectrum. The sole "easy" responses for ease of entire meal consumption were observed in the potato condition, and the only “very easy” responses were observed in the potato & egg condition. Consumption responses in percentages for each condition are seen in table 5.9 below.

Table 5.9: Rating percentages of ease of consumption perceptions

How did you find the ease of consuming the entire meal?	**Not Easy**	**Somewhat Easy**	**Neutral**	**Easy**	**Very Easy**
Lentil	73%	9%	18%	0%	0%
Potato	30%	30%	30%	10%	0%
Potato & Egg	44%	11%	11%	0%	11%

Responses for question 3 from the test meal analysis are expressed in percentages of responses for each option on the rating scale.

Ease of chewing and swallowing the pre-exercise meals was assessed in question seven of the test meal analysis. A main effect of meal condition on ease of meal consumption was identified ($p<0.05$). Post-hoc comparisons identified a significant difference in palatability between the potato and lentil conditions ($p<0.05$). The lentil meal was rated as the hardest to consume (1), no significant difference was observed between the two high protein meals. Ratings of “not easy” to consume were only observed in the lentil condition, “somewhat easy” ratings were only observed in the potato & egg and lentil meals, and the potato & egg meal received the only ratings of “very easy” to consume. No significant differences between any of the other meal conditions was observed ($p<0.05$). The potato meal was rated as the easiest to consume (3) as responses were only observed in the “neutral” and “easy” ranks. Table 5.10 illustrates the response percentages for each condition regarding the ease of chewing and swallowing.

Table 5.10: Rating percentages of palatability perceptions

How did you find the ease of chewing and swallowing of the meal?	**Not Easy**	**Somewhat Easy**	**Neutral**	**Easy**	**Very Easy**
Lentil	27%	27%	36%	9%	0%
Potato*	0%	0%	44%	56%	0%
Potato & Egg	0%	38%	25%	13%	25%

Responses for question 7 from the test meal analysis are expressed in percentages of responses for each option on the rating scale. * - a significant difference between the meal conditions was observed as the potato meal was rated as more easily consumed than the lentil meal.

Pre-exercise meal size and ease of entire meal consumption ratings reflected similar responses for each experimental condition, where the majority of responses for meal size was large and the meals were primarily rated as “not easy” to consume the entire portion. A main effect of meal condition on meal texture was identified ($F=4.424$, $p<0.05$). Post-hoc comparisons identified a significant difference between the texture of the lentil (54% negative ranks) and potato (0% negative ranks) meals ($p< 0.05$). No significant differences were observed between the potato and potato & egg meals, or the potato & egg and lentil meals. Only one participant in the lentil condition rated the texture of the meal as “not tolerable”. The majority of potato condition responses for texture palatability were “tolerable”, and the majority of lentil responses were slightly more negative: “somewhat tolerable” (Table 5.11). One participant in the potato & egg condition rated meal texture as “very tolerable”. The lentil meal was perceived to be less tolerable for texture palatability than the potato meal, but no substantial difference was observed between the participants’ perceptions of the lentil and potato & egg meals.

Table 5.11: Rating percentages of texture perceptions

What is the texture of the meal?	**Not Tolerable**	**Somewhat Tolerable**	**Neutral**	**Tolerable**	**Very Tolerable**
Lentil	9%	45%	27%	18%	0%
Potato*	0%	0%	33%	66%	0%
Potato & Egg	0%	25%	38%	25%	13%

Responses for question 6 from the test meal analysis are expressed in percentages of responses for each option on the rating scale. * - a significant difference between the meal conditions was observed as the potato meal was rated more positively for texture than the lentil meal.

5.2.2.4. Aromatic Perceptions

Question four and five used 3-point scales to assess perceptions of meal aroma: 1 = yes, 2 = no and 3 = I don’t know and are expressed as percentages in Table 5.12 below. No significant differences between the meal conditions for aroma were observed. The majority of responses in the lentil and potato conditions indicated no aromas observed. In contrast, the potato & egg meal responses were primarily “yes” the meal did have an aroma. On average, all meals elicited average scores of 1: “yes”, there was an aroma.

Question five found 22% of responses for the potato condition as “yes” the aroma was appealing. Most participants rated all meals as “I don’t know” for the appealing quality of aroma

(Table 5.13). Statistical analysis did not determine significant differences of aroma appeal between the meal conditions.

Table 5.12: Rating percentages of aromatic perceptions

Did the meal have an aroma?	**Yes**	**No**	**I don't know**
Lentil	18%	64%	18%
Potato	30%	60%	10%
Potato & Egg	63%	38%	0%

Responses for questions 4 of the test meal analysis are expressed in percentages of responses for each option on the rating scale.

Table 5.13: Rating percentages of aromatic perceptions

Is the aroma of the meal appealing?	**Yes**	**No**	**I don't know**
Lentil	0%	50%	50%
Potato	22%	22%	56%
Potato & Egg	0%	25%	75%

Responses for question 5 from the test meal analysis are expressed in percentages of responses for each option on the rating scale.

5.2.2.5. Exercise Readiness Perceptions

Question nine investigated feelings regarding the ease of exercise after meal consumption and the majority of responses in the potato and potato & egg meals were "yes", they would feel ready to exercise. Statistical tests did not identify significant differences between the meal conditions for this question. Twenty-seven percent of the lentil participants responded "no" they would not be ready to exercise at the beginning of the testing. Many of the participants rated their readiness to exercise as unknown. The responses for question nine are illustrated as percentages of total responses in the table below (5.14).

Table 5.14: Rating percentages of exercise readiness

Do you feel you will be able to exercise with ease at the beginning of the testing?	**Yes**	**No**	**I don't know**
Lentil	45%	27%	27%
Potato	78%	0%	22%
Potato & Egg	71%	0%	29%

The response for question 9 from the test meal analysis are expressed in percentages of responses for each option on the rating scale.

5.2.2.6. Qualitative Assessment

Qualitative feedback for this section of the TMA was not mandatory. The collected responses are shown in Table 5.15 (see below), and demonstrate the dislike of the participants for all the fed conditions; specifically, their taste, size and smell.

Table 5.15: Sensory test meal analysis qualitative comment section results

Question	Lentil	Potato & Egg	Potato
1. How did the meal look?	• The colour and texture looked gross. Upon looking at it I already did not want to consume it. • Smelt good. Taste Crap. • Didn't look gross but didn't look good either. • red mush, it looked a little odd but was not disgusting.	• The appearance was less than desirable. Pretty gross looking. • The meal looked better than the lentil meal, however it isn't something I would eat on a daily basis.	• Lacked colour. • Gorgeous to look at. I wish I had a picture to remind me of its awesomeness! • Mashed potatoes didn't look too bad.
2. What did you think about the size of the meal?	• Ridiculously large. All because the container is that size doesn't mean you have to fill the whole container.	• Far too large a serving to reasonably consume for my body weight with only water. • Could have probably finished, but it was really gross to eat. I was still hungry before the test but I couldn't finish cause it was gross. • Way too much to try and eat in 15 minutes. Maybe if it tasted better I could down it in 15 minutes, but otherwise I couldn't. • The meal was extremely large, I was unable to consume the entire meal.	• I would have eaten more if there was more. Just kidding. As usual, it was way too large.
3. How did you find the ease of consuming the entire meal?	• It is difficult consuming that much food especially in the morning. I think I would be able had it been like a lunch meal. • Tasted crap. • Texture and taste suck. • Combination of large size and unpalatable nature. • I have trouble eating in the morning.	•	• I had difficulties because like most Canadians my morning do not regularly consist of 9lbs of mash potatoes and ketchup. • (I) didn't have enough time. • I didn't complete the meal. • Dryness and no taste.
4. Did the meal have an aroma?	• Never really smelt lentils before.	• Nothing over-baring. • Not a good aroma. • It was not the greatest smell. But the smell went away after a while. • It smells like eggs, not great though.	• Smelt potatoes
5. Is the aroma of the meal appealing?	• It was a bit grainy/rough.	• It is not an appealing aroma, however it was not absolutely dreadful either.	• You should bottle the aroma and sell it as an upscale perfume. • A bit.

6. What is the texture of the meal?	• The texture made me want to hurl. Ever(y) bit I felt like throwing up just a little. • Same as above, kinda grainy.	• The chunky egg whites mixed with the instant potatoes produced an undesirable texture. • The potatoes had a good texture and were nice and smooth. However, the chunks of egg white gave the meal an overall poor texture and it was difficult to chew and swallow at times.	• It was tolerable up until a certain point, and then it lost all of its appeal.
7. How did you find the ease of chewing and swallowing the meal?	• I tried to just stick it in my mouth and swallow the meal, but I couldn't stomach the texture and taste. • Lentils themselves weren't great, ketchup helped a lot.	• I'll be honest. I was struggling to swallow from the onset of the meal. Only the water made the meal tolerable. • To start it was easy. At the end it almost got to the point where I felt like vomiting. Thought cause of the taste, didn't feel as good going down.	•
8. The flavour of the meal was?	• Gross • Gross • No flavour	• Got worse the more I ate. • Disgusting. • The flavour was bearable for the first five minutes. It became gross after a while and my taste buds could not handle it. I gagged a few times and nearly threw up.	• Not a lot of flavour.
9. Do you feel you will be able to exercise with ease at the beginning of the testing (in approximately 2 h)? If no, why not?	• My stomach is so full!! • Meal was a bit big maybe. • Don't feel I took enough food in.	• I gagged on my last bit and felt somewhat nauseous. After 2 hours exercising will not be an issue. • No. Very uncomfortable. • Yes, with ease. -I think I'm set to go. • Yes, I felt fresh, lots of energy. • Yes, the meal is very filling but I believe I will be alright. • In addition: Was really hungry at half but didn't want to eat the gross stuff cause it made me want to puke.	• Not overly stuffed. • I might get hungry again and feel a little discomfort at the start.

5.2.3. Post-prandial Digestive Symptoms

A significant main effect of meal condition on hunger was identified ($p<0.05$). Post hoc analyses revealed there was greater hunger in the un-fed control condition (2.1±0.69) compared to the three fed pre-exercise meal conditions (Table 5.16). A significant main effect of meal condition on fullness was also identified ($p<0.05$). Post hoc analyses revealed there was greater fullness in both the high protein conditions (lentil = 1.8 ± 0.7, potato & egg = 1.6 ± 0.7) compared to the control and low protein conditions. A significant main effect of meal condition on nausea was also identified ($p<0.05$). Post hoc analyses depicted a slight increase in the severity of nausea symptoms experienced by the participants during the lentil pre-exercise meal condition (see Table 5.16 for mean values and observed significance) when compared to the other fed pre-exercise conditions. The mean values and significant differences for the remaining digestive symptoms are located below in Table 5.16.

Table 5.16 Digestive symptoms rating scale mean values (n=13)

	Fullness	**Hunger**	**Nausea**	**Bloating**	**Abdominal Cramping**
Control	0.3	2.1*	0.1	0.1	0.1
Lentil	1.8**	0.9	1.0*^	0.4	0.1
Potato & Egg	1.6**	0.6	0.5	0.4	0.1
Potato	0.4	0.7	0.3	0.3	0.1
STDEV	0.7	0.69	0.39	0.18	0.02

The digestive symptoms rating scale assessed participant symptom severity on a 5 point scale (0=no; 1=mild; 2=moderate; 3=moderately severe; and 4=severe, symptoms). The mean values (n=13) are the averages of nine collected time points throughout each trial. * = significantly more severe symptoms than all other conditions; ^ = significantly more severe symptoms than all other fed conditions; ** = significantly more severe symptoms than control and potato conditions. Statistical significant is achieved at $p<0.05$.

5.2.3.1. Fullness

Baseline measurements of fullness revealed that the majority of responses had no or mild severity of fullness symptoms (Table 5.17). During meal consumption, from approximately -140 minutes to -105 minutes, participants rated fullness severity from moderate to severe symptoms. After meal consumption 92%, 86% and 76% of responses indicated moderate to severe symptoms in the lentil, potato, and potato & egg meals, respectively, but only 31%, 23%, 46% for lentil, potato, and potato & egg, respectively, of responses were severe regardless of inadequate meal consumption. Ninety minutes prior to exercise more than three-quarters of the fed participants rated symptoms of fullness as moderate or moderately severe. Immediately prior to exercise no participants rated fullness symptoms as severe, and no difference was observed between the responses from participants who had consumed a meal. Ninety minutes into exercise testing no respondents rated fullness severity as moderately severe or severe.

Table 5.17. Fullness symptoms ratings

Meal Condition	**Fullness Severity**	**Time-point (min)**								
		-140	**-120**	**-105**	**-90**	**-60**	**0**	**45**	**90**	**105**
Lentil	No symptoms	69	8	8	0	23	8	8	23	31
	Mild symptoms	15	0	0	8	8	31	54	62	54
	Moderate symptoms	8	23	23	31	31	46	23	15	15
	Moderately Severe	8	38	31	46	38	15	15	0	0
	Severe Symptoms	0	31	38	15	0	0	0	0	0
Potato	No symptoms	77	0	0	0	0	15	31	31	31
	Mild symptoms	15	15	15	23	23	23	31	46	54
	Moderate symptoms	0	0	8	46	46	46	38	23	8
	Moderately Severe	8	62	62	31	31	15	0	0	8
	Severe Symptoms	0	23	15	0	0	0	0	0	0
Potato & Egg	No symptoms	54	0	0	0	0	8	23	46	31
	Mild symptoms	31	0	0	0	15	31	38	46	54
	Moderate symptoms	15	15	23	31	31	54	38	8	15
	Moderately Severe	0	38	38	62	54	8	0	0	0
	Severe Symptoms	0	46	38	8	0	0	0	0	0
Control	No symptoms	46	54	69	69	69	77	77	85	85
	Mild symptoms	38	31	23	23	23	15	23	15	15
	Moderate symptoms	15	15	8	8	8	8	0	0	0
	Moderately Severe	0	0	0	0	0	0	0	0	0
	Severe Symptoms	0	0	0	0	0	0	0	0	0

The fullness responses from the digestive symptoms rating scale are expressed as the percentage of total responses in each of the ranks of the Likert scale. The participants completed the scale at 9 time-points throughout each of the 4 experimental tests.

5.2.3.2. Hunger

Baseline hunger severity ratings were moderate or moderately severe for the majority of participants. Almost all fed responses were “no symptoms” or “mild symptoms” of hunger severity with the first postprandial assessment (Table 5.18) as the participants arrived to the laboratory in a fasted state. Ninety minutes prior to exercise, 15% of lentil responses identified moderate hunger severity. As testing elapsed the general trend was for hunger severity to increase. Immediately prior to exercise a larger portion of lentil and control responses were moderate in hunger severity. Despite proportional amounts of the potato and potato & egg meals consumed participants did not record moderate severity of hunger as seen prior to exercise in the lentil responses. Half-time potato and potato & egg responses shifted toward more severe hunger symptoms. After the 5th of 6 fifteen minute exercise blocks all fed conditions had 30% or greater response percentage in moderate and moderately severe ratings. Observations of hunger severity are illustrated below (Table 5.18).

Table 5.18: Hunger symptoms ratings

Meal Condition	**Hunger Severity**	**Time-point (min)** -140	-120	-105	-90	-60	0	45	90	105
Lentil	No symptoms	8	69	69	62	54	54	54	54	54
	Mild symptoms	15	23	31	23	8	8	8	8	0
	Moderate symptoms	31	8	0	15	38	38	31	15	15
	Moderately Severe	38	0	0	0	0	0	8	23	31
	Severe Symptoms	0	0	0	0	0	0	0	0	0
Potato	No symptoms	8	92	92	92	92	69	46	46	54
	Mild symptoms	15	8	8	0	0	23	23	15	8
	Moderate symptoms	23	0	0	0	8	8	31	31	23
	Moderately Severe	46	0	0	0	0	0	0	8	8
	Severe Symptoms	8	0	0	0	0	0	0	0	8
Potato & Egg	No symptoms	15	85	85	85	85	77	62	54	46
	Mild symptoms	15	15	15	15	15	23	15	15	15
	Moderate symptoms	38	0	0	0	0	0	23	15	15
	Moderately Severe	31	0	0	0	0	0	0	15	8
	Severe Symptoms	0	0	0	0	0	0	0	0	15
Control	No symptoms	0	15	15	15	15	8	8	8	8
	Mild symptoms	31	38	38	31	31	23	8	0	23
	Moderate symptoms	46	31	15	15	15	23	46	54	23
	Moderately Severe	0	0	0	0	0	0	0	0	0
	Severe Symptoms	0	0	0	0	0	0	0	0	0

The hunger responses from the symptoms rating scale are expressed as the percentage of total responses in each of the ranks of the Likert scale. The participants completed the scale at 9 time-points throughout each of the 4 experimental tests.

5.2.3.3. Bloating

As expected when arriving fasted, nearly all respondents' identified no or mild symptoms of bloating at baseline. During meal consumption, response percentages of moderate to moderately severe increased (Table 5.19); immediately after consumption the majority of participants indicated no or mild bloating symptoms. Ninety minutes prior to exercise no participants rated bloating as severe. One hour prior to exercise lentil responses indicated less bloating than potato: 85% lentil, 77% potato, and 62% potato & egg (% of no symptoms), which can perhaps be attributed to the sodium content of the instant mashed potatoes. Immediately prior to exercise no or mild ratings were observed by 85%-100% of the all the fed participants' responses. Sub-optimal exercise performance cannot be attributed to adverse feelings of bloating as no symptoms of bloating were rated from game time to 105 minutes.

Table 5.19: Bloating symptoms ratings

Meal Condition	**Bloating Severity**	**Time-point (min)**								
		-140	**-120**	**-105**	**-90**	**-60**	**0**	**45**	**90**	**105**
Lentil	No symptoms	77	46	54	46	85	62	85	85	85
	Mild symptoms	15	31	31	38	15	23	8	8	8
	Moderate symptoms	8	23	8	8	0	15	8	8	8
	Moderately Severe	0	0	8	8	0	0	0	0	0
	Severe Symptoms	0	0	0	0	0	0	0	0	0
Potato	No symptoms	85	62	62	69	77	69	85	92	92
	Mild symptoms	15	15	31	31	23	31	15	8	0
	Moderate symptoms	0	15	8	0	0	0	0	0	8
	Moderately Severe	0	8	0	0	0	0	0	0	0
	Severe Symptoms	0	0	0	0	0	0	0	0	0
Potato & Egg	No symptoms	85	62	62	62	62	77	92	92	92
	Mild symptoms	15	0	8	15	31	23	8	8	8
	Moderate symptoms	0	23	15	8	8	0	0	0	0
	Moderately Severe	0	8	8	15	0	0	0	0	0
	Severe Symptoms	0	8	8	0	0	0	0	0	0
Control	No symptoms	92	92	92	92	100	100	100	100	92
	Mild symptoms	0	8	8	8	0	0	0	0	8
	Moderate symptoms	8	0	0	0	0	0	0	0	0
	Moderately Severe	0	0	0	0	0	0	0	0	0
	Severe Symptoms	0	0	0	0	0	0	0	0	0

The bloating responses from the symptoms rating scale are expressed as the percentage of total responses in each of the ranks of the Likert scale. The participants completed the scale at 9 time-points throughout each of the 4 experimental tests
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5.2.3.4. Nausea

Assessment of baseline ratings of nausea revealed no responses of moderately severe or severe symptoms (Table 5.20), but some of the participants rated moderate or lower nausea symptom severity attributable to arriving to the laboratory in a fasted state. Immediate post-prandial ratings found the majority of responses as mild or no nausea (Table 5.20).

Table 5.20: Nausea symptoms ratings

Meal Condition	**Nausea Severity**	**Time-point (min)**								
		-140	**-120**	**-105**	**-90**	**-60**	**0**	**45**	**90**	**105**
Lentil	No symptoms	85	46	62	69	77	85	77	92	92
	Mild symptoms	15	31	23	15	15	15	23	8	8
	Moderate symptoms	0	8	8	8	0	0	0	0	0
	Moderately Severe	0	8	0	0	8	0	0	0	0
	Severe Symptoms	0	8	8	8	0	0	0	0	0
Potato	No symptoms	77	77	85	85	85	69	85	85	69
	Mild symptoms	8	15	8	15	15	23	15	15	15
	Moderate symptoms	15	8	8	0	0	8	0	0	15
	Moderately Severe	0	0	0	0	0	0	0	0	0
	Severe Symptoms	0	0	0	0	0	0	0	0	0
Potato & Egg	No symptoms	85	54	54	69	77	85	85	85	69
	Mild symptoms	15	38	46	31	23	15	15	15	23
	Moderate symptoms	0	8	0	0	0	0	0	0	8
	Moderately Severe	0	0	0	0	0	0	0	0	0
	Severe Symptoms	0	0	0	0	0	0	0	0	0
Control	No symptoms	85	92	92	92	85	69	69	69	62
	Mild symptoms	8	8	8	0	0	31	31	15	23
	Moderate symptoms	8	0	0	8	15	0	0	15	8
	Moderately Severe	0	0	0	0	0	0	0	0	8
	Severe Symptoms	0	0	0	0	0	0	0	0	0

Nausea responses from the symptoms rating scale are expressed as the percentage of total responses in each of the ranks of the Likert scale. The participants completed the scale at 9 time-points throughout each of the 4 experimental tests.

A small percentage of responses rated moderate, moderately severe or severe nausea symptoms. The second and third post-prandial ratings found the majority of responses as absent no or mild nausea severity for all the experimental conditions even fasted control. Immediately prior to exercise no responses of moderately severe or severe were observed. At game time no symptoms of nausea were rated by 85% lentil, 69% potato, 85% potato & egg, but only 69% control participants. Throughout exercise control participants rated mild to moderate nausea severity: 69% or greater. Immediately prior to the sprint tests responses of no symptoms of nausea changed drastically in the potato, potato & egg, and control conditions, but there was no change from pre-sprint (90 min) test to post-sprint test (105 min) ratings of nausea in only the lentil condition (Table 5.20).

5.2.3.5. Abdominal Cramping

All participants rated abdominal cramping severity as absent or mild at baseline (Table 5.21). Post-prandially, the vast majority of participants rated abdominal cramping severity as no or mild symptoms. Contrary to the lentil condition, ratings of abdominal cramping severity immediately after the 5th fifteen minute exercise block identified changes in the potato and potato & egg meal responses: ratings increased in severity throughout the sprint test and post-sprint test. After exercise lentil and control conditions were consistent while the two potato condition's abdominal cramping severity responses increased.

Table 5.21: Abdominal cramping symptoms ratings

Meal Condition	**Abdominal Cramping Severity**	**Time-point (min)** -140	**-120**	**-105**	**-90**	**-60**	**0**	**45**	**90**	**105**
Lentil	No symptoms	92	77	85	85	100	92	92	92	92
	Mild symptoms	8	15	8	8	0	8	8	8	8
	Moderate symptoms	0	8	8	8	0	0	0	0	0
	Moderately Severe	0	0	0	0	0	0	0	0	0
	Severe Symptoms	0	0	0	0	0	0	0	0	0
Potato	No symptoms	85	100	100	100	100	92	92	77	69
	Mild symptoms	8	0	0	0	0	8	8	23	31
	Moderate symptoms	0	0	0	0	0	0	0	0	0
	Moderately Severe	8	0	0	0	0	0	0	0	0
	Severe Symptoms	0	0	0	0	0	0	0	0	0
Potato & Egg	No symptoms	92	92	85	92	85	85	100	92	85
	Mild symptoms	8	8	15	8	15	15	0	0	0
	Moderate symptoms	0	0	0	0	0	0	0	8	15
	Moderately Severe	0	0	0	0	0	0	0	0	0
	Severe Symptoms	0	0	0	0	0	0	0	0	0
Control	No symptoms	92	92	92	92	92	92	92	85	92
	Mild symptoms	8	8	8	8	8	8	8	15	8
	Moderate symptoms	0	0	0	0	0	0	0	0	0
	Moderately Severe	0	0	0	0	0	0	0	0	0
	Severe Symptoms	0	0	0	0	0	0	0	0	0

Abdominal Cramping responses from the symptoms rating scale are expressed as the percentage of total responses in each of the ranks of the Likert scale. The participants completed the scale at 9 time-points throughout each of the 4 experimental tests.

5.2.4. Consumption and Exercise Performance

Total sprint distances (m) were similar between the three fed experimental conditions: lentil, potato & egg, and potato (1508 ± 178 m, 1500 ± 174 m, 1507 ± 179 m; respectively for lentil, potato & egg, and potato as means ± SD). Additionally, as shown with orthogonal contrasts of the treatments, each fed condition produced significantly greater total sprint distances (m) than the unfed control condition (1369 ± 170 m) (lentil vs. control, p= 0.019; potato & egg vs. control, p = 0.006; potato vs. control, p = 0.005) . Statistical analysis of data from the repeated sprint tests, as per Little et al., (2010), found a significant effect of experimental condition on sprint distance covered ($p = 0.05$); post hoc tests identified a greater distance covered in sprint 1 from lentil meal consumption than control (310.5 ± 40 m vs. 295.1 ± 32.4 m, respectively), and a greater distance covered in sprint 2 from lentil and potato & egg meal consumption compared to control (305 ± 35.2 m, 307.7 ± 31.6 m, and 291.7 ± 35.4 m, respectively).

Individual participant OPS, and average distance covered across four conditions, are shown in table 5.22. The 24 h energy intake amounts ranged from 28.7 - 61.1 kcal·kg^{-1}, with an average intake of 44.0 ± 9.0 kcal·kg^{-1} (Table 5.22). Total carbohydrate intake is also depicted in table 5.22: lowest, highest, and average values of 4.2, 8.8, and 5.8 ± 1.4, g /kg. Linear relationships investigated with Pearson's correlation coefficient identified moderate correlations between overall performance score and total energy (kcal·kg^{-1}), $r = 0.61$ ($p<0.05$); overall performance score and pre-exercise meal energy (kcal·kg^{-1}), $r = 0.68$ ($p < 0.01$); and overall performance score and pre-exercise meal carbohydrate (g·kg^{-1}), $r = 0.67$ ($p < 0.01$). A weak correlation was identified between overall performance score (m) and total carbohydrate intake (g·kg^{-1}), $r = 0.41$ ($p<0.05$). Further investigation of the relationships between energy and carbohydrate intake and exercise performance were facilitated by the generation of high and low intake groups (Table 5.23). Statistical analysis performed to identify differences in overall sprint distance covered (OPS) between high and low energy intake from the pre-exercise meal alone did not produce a significant difference between the groups. Statistical analysis performed to identify differences in overall sprint distance covered (OPS) between high and low carbohydrate intake from the pre-exercise meal alone also did not produce a significant difference between the groups. A significant difference in distance covered as OPS was found between the high and low total carbohydrate intake groups ($p < 0.05$; $F = 17.339$) (Table 5.22), with higher carbohydrate intake associated with a greater OPS. A significant difference was also identified between the high and low total energy groups (Table 5.22) across the OPS, whereby the high energy group had a higher OPS than the low energy group ($p < 0.01$, $F = 17.845$).

Table 5.22: Energy, carbohydrate and performance variables

Participant	Total Energy ($kcal \cdot kg^{-1}$)	Total Carbohydrate ($g \cdot kg^{-1}$)	Meal Energy ($kcal \cdot kg^{-1}$)	Meal Carbohydrate ($g \cdot kg^{-1}$)	OPS (m)
1	61.1	6.4	9.8	1.3	1683
2	28.7	4.3	6.5	1.0	1386
3	51.8	8.1	9.1	1.3	1674
4	51.3	5.8	10.2	1.4	1736
5	53.5	8.8	10.6	1.5	1753
6	37.7	5.6	9.2	1.3	1339
7	42.7	5.7	8.9	1.2	1474
8	56.8	6.6	10.0	1.4	1539
9	39.5	4.4	7.6	1.0	1414
10	46.3	7.5	9.2	1.3	1325
11	40.6	4.2	6.9	1.0	1483
12	44.4	6.2	7.1	1.0	1202
13	53.1	6.5	7.9	1.1	1418
AVG	44.0*	5.8	8.7*	1.2*	1400
STDEV	9.0	1.4	1.4	0.2	173

24 h total energy and total carbohydrate were determined with Diet Analysis+v.8. OPS (m) = Overall Performance Score, is the distance average covered in the repeated sprint test for each trial. Values, averages, and standard deviations are expressed relative to body weight (kg) and all carbohydrate values include fibre. * Moderate correlations were identified between the intake variable and OPS (m) such that $r > 0.6$, $p < 0.05$.

Table 5.23: High and Low Energy and Carbohydrate Intake Groups

	Total Energy ($kcal \cdot kg^{-1}$)	Total Carbohydrate ($g \cdot kg^{-1}$)	Meal Energy ($kcal \cdot kg^{-1}$)	Meal Carbohydrate ($g \cdot kg^{-1}$)
Low Group	40.0 ± 5.8	5.0 ± 0.8	7.7 ± 1.0	1.1 ± 0.1
High Group	54.6 ± 3.7	6.9 ± 0.8	9.8 ± 0.6	1.3 ± 0.05

Values are expressed relative to body weight (kg) and as averages ± SD.

5.2.5. Questionnaire Results

Twelve of thirty young male athletes involved in this research returned the consent forms (Appendix A2.2) and completed questionnaires. The results obtained from the 12 completed questionnaires were also employed in a subsequent similar study for improved power and validity (Bennett et al., 2012).

5.2.5.1. Demographic Information

All of the participants, mean age of 25 ± 3 y, rated their health as good, very good and excellent, with 66.7% in the very good to excellent category. Most respondents also indicated that they had some type of employment, and only one responded that he was solely a student. All of the respondents had completed some university, with 50% completing some graduate studies. Of the participants, 75% reported living in households with less than three people, and income levels were evenly distributed with 50% indicating a yearly household income less than $49,999, and 50% indicating a yearly household income greater than $50,000. All of the participants were omnivorous in their dietary practices, and 66.7% had received university level nutrition training. Three quarters of participants exercised 5 or more sessions per week with 91.7% completing exercise sessions longer than 41-60 minutes. Participants' responses regarding weekly pulse-based consumption was moderate with 58% of responses indicating 1 or fewer servings of pulses (lentils, peas, chick peas) per week. As seen in figure 5.1 below, 23% of participants chose pulses zero times per week, 38% chose pulses once per week, 23% chose pulses twice per week, 8% chose pulses both three and six times per week. All participants recorded low to negligent lentil intake: indicating weekly consumption of 1 (38%) or no (62%) servings of lentils.

5.2.5.2. Nutrition Knowledge

The average nutrition knowledge score obtained from the thirteen participants was 63 ± 14% with a range of 26% to 75%, while the athlete nutrition subgroup average score was 53 ± 10%. Relationships between the cognitive concepts of attitudes and beliefs and variables of demographics, pulse and lentil consumption, and nutrition knowledge investigated in the questionnaire were determined with correlations. Subgroups investigated in the general nutrition knowledge portion of the questionnaire are listed in table 5.24 below, along with the mean scores and number of items contributing to the subgroup score. A significant correlation was determined between overall general nutritional knowledge score and education level (r = 0.6), but no significance was identified between formal nutritional knowledge training and overall nutritional knowledge ($p > 0.05$). Correlations between age and general nutritional knowledge score, or pulse consumption and beliefs and barriers did not deliver any significant correlations. However, a strong positive correlation was identified between the number of exercise sessions performed/week to the overall general nutrition score (r = 0.733, $p < 0.05$, as well as the athlete specific nutrition knowledge score to overall general nutrition score (r = 0.786, $p < 0.05$). Participants scored well in several subgroups investigated in the nutritional knowledge portion of the questionnaire, specifically subgroups of iron (71%), functional foods (83%), vegetables (67%), and hydration (81%) obtained the highest mean percentages of all the investigated subgroups. The athletes scored poorest when asked about macronutrients (carbohydrates 55%, protein 56%, and fat 54%), vitamins (53%), health benefits of foods (53%), and nutrition for the athlete (52%).

Table 5.24: Subgroup and total scores for general nutritional knowledge (n = 12)

		Mean percentage score	Number of questions in category
1	**Carbohydrates**	55	5
2	**Protein**	56	3
3	**Fats**	54	4
4	**Calcium**	54	6
5	**Iron**	71	6
6	**Vitamins**	53	13
7	**Functional Foods**	83	3
8	**Vegetables**	67	4
9	**Health benefits of foods**	53	3
10	**Hydration**	81	9
11	**Nutrition for the athlete**	52	6
12	**Weight loss**	64	3
Total		62	65

The general nutritional knowledge section, as per Zawila et al., 2003, of the questionnaire contained 12 subgroups to identify specific nutrition knowledge. In addition to the overall general nutritional knowledge score, scores from subgroup questions were averaged to generate subgroup specific scores. Results as means are expressed as percentages.

5.2.5.3. Beliefs and Barriers

Responses from the section of the questionnaire investigating beliefs and barriers towards pulse-based meals are presented in tables 5.25 and 5.26. No significant correlation was identified between weekly pulse consumption and agreement with the belief and barrier statements. A strong negative correlation existed between the average overall barrier score and weekly pulse consumption greater than or equal to one serving ($r = -0.905$, $p < 0.05$). While a moderate to strong positive correlation was identified between the overall belief score and participant agreement with the benefits associated with pulse-based meals ($r = 0.620$, $p < 0.05$). Analysis of the practical barriers "Someone else decides most of the foods that I eat" and "My family/partner won't eat a meal containing pulses" also produced a significant correlation ($r = -0.674$, $p < 0.05$), although no other significant correlations existed between the other practical barriers.

The relationships of nutrition knowledge score and athlete specific nutrition knowledge score to pulse and lentil consumption per week were also investigated. No significant relationships were identified between the pulse and lentil consumption amounts of the participants and any aspect of their nutrition knowledge.

Participants strongly agreed with the barriers stating they did not know how to prepare pulse-based meals (75%), and that they needed more information about pulses (58%). Participants strongly disagreed with the following barriers: their family/partner wouldn't eat a meal containing pulses (83%), someone else decides the foods they eat (75%) or prepares their meals (83%), a pulse-based meal would not be filling enough (75%), they may be thought of as strange or a hippy (100%), and that they may not have enough will power (92%). Pulse-based meal benefit statements producing strong agreement from the participants included: pulse-based meals … help me to eat a greater variety of food (75%), … are a good source of protein (92%), … help decrease my saturated fat intake (92%),… improve my digestion (84%), and …help prevent disease in general (75%).

Table 5.25: Response percentages of barriers toward eating pulse-based meals (n = 12)			
	% of Respondents		
Statement	Agree[1]	Unsure	Disagree[1]
I don't know how to prepare pulse-based meals	75	17	8
Pulse-based meals or snacks are not available when I eat out	42	25	25
I'm too busy to prepare a pulse-based meal, I need something that's easier to consume on the run	25	17	58
My family/partner won't eat a meal containing pulses	0	17	83
It would not be tasty enough	58	25	17
Someone else decides most of the foods that I eat	17	8	75
Someone else prepares my meals	17	0	83
I would have to go shopping too often	0	33	67
It would not be filling enough	0	25	75
I need more information about pulses	58	8	33
There's not enough protein in them	8	25	67
I would get indigestion, bloating, gas or flatulence	42	42	16
It would be too expensive	8	33	58
I don't want to change my eating habits or routine	33	25	42
I don't want people to think I'm strange or a hippy	0	0	100
I wouldn't get enough energy or strength	0	25	75
I don't want to eat strange or unusual foods	8	0	92
There is not enough iron in them	0	42	58
I would need to eat such a large quantity of food	17	25	67
It takes too long to prepare a pulse-based meal	42	25	33
It is inconvenient	33	33	33
I don't have enough willpower	8	0	92

(1) Agreement responses ("Strongly agree" and "agree") and disagreement responses ("Strongly disagree" and "disagree) were grouped respectively.

Table 5.26: Response percentages of benefits of eating pulse-based meals (n = 12)			
	% of Respondents		
Statement[1]	Agree[2]	Unsure	Disagree[2]
Stay healthy	50	42	8
Have lots of fibre	50	50	0
Help me to eat a greater variety of foods	75	17	8
A good source of protein	92	8	0
Have lots of vitamins and minerals	50	42	8
Have a better quality of life	33	42	25
Control my weight	42	42	17
Help decrease my saturated fat intake	92	8	0
Help the environment	33	58	8
Improve my digestion	84	8	8
Be fit	33	33	33
Be part of a tasty diet	42	50	8
Improve my energy levels throughout the day	58	42	0
Help prevent disease in general (e.g. heart disease, diabetes)	75	8	17
Save money	8	42	50
Be more content with myself	0	17	83

(1) Questions were led with "I believe that pulse-based meals can help me to" or "I believe that pulse-based meals can" or "I believe pulse-based meals are"
(2) Agreement responses ("strongly agree" and "agree") and disagreement responses ("strongly disagree" and "disagree) were grouped respectively.

5.3. Discussion

The purpose of this research study was to examine the viability of lentils as a pre-exercise meal able to elicit optimal performance in athletes undergoing high-intensity intermittent exercise. The Dietitians of Canada and American Dietetic Associations, two bodies responsible for generating guidelines for sport nutrition, have made recommendations with respect to the nutritional and sensory aspects of optimal pre-exercise meals that can lead to improved performance (Kreider et al., 2010; Rodriguez et al., 2009). Such meals have a specific macronutrient profile and composition, including low fat and fibre, moderate protein, and high carbohydrate content, the ability to maintain hydration, and a metabolic environment that enables energy provision and improves performance outcomes (Kreider et al., 2010; Rodriguez et al., 2009). In addition to these nutritional aspects, acceptability aspects such as familiarity and tolerability, sensory perception requirements, and gastrointestinal and digestive requirements as outlined by the International Federation of Sports Medicine and the American Council of Sports Medicine are key (Deibert et al., 2005; Rodriguez et al., 2009).

Four hypotheses were tested to determine if lentils could be an optimal and acceptable pre-exercise meal for athletes of high intensity intermittent exercise. A pre-exercise meal sensory analysis was employed to investigate the first hypothesis that stated the sensory aspects of lentils as a pre-exercise meal would not differ from those of the other pre-exercise meals. This hypothesis was partially supported as the lentil meal was similar to the potato & egg meal for several of the assessed sensory perceptions; specifically, the lentil and potato & egg meals were perceived similarly by the participants for visual, taste, size, flavour, ease of consumption. However, the first hypothesis was not strongly supported as the potato meal was consistently more positively rated across the majority of the sensory perceptions assessed. A second examination tool, the digestive symptoms rating scale, investigated the hypothesis indicating the digestive symptoms associated with lentil pre-exercise meal consumption would not differ from the digestive symptoms associated with other similar pre-exercise meals. The lentil meal produced similar digestive symptoms of abdominal cramping, bloating and hunger compared to the potato and potato & egg meals supporting the hypothesis. The hypothesis was partially supported from the findings regarding digestive symptoms of fullness as the lentil meal and the potato & egg meal were similar, but the lentil meal was not similar to the potato meal. Symptoms of nausea experienced following the lentil meal were greater at the onset of experimental testing, but towards the end of exercise greater increases in nausea were seen in the potato & egg and potato meals compared to the lentil meal. The third hypothesis stated 'the total energy and carbohydrate amounts consumed in a pre-exercise meal affect sport performance'. To test this hypothesis we investigated the effect high and low energy and carbohydrate amounts and the participants' overall sport performance. Moderate correlations between overall performance score and each pre-exercise meal energy ($r=0.68$) and carbohydrate ($r = 0.67$), $p < 0.05$, were identified and supported the third hypothesis. Our results also identified improvements in total sprint distance (m) when a pre-exercise meal was consumed compared to exercise in a fasted state (lentil vs. control, $p= 0.019$; potato & egg vs. control, $p = 0.006$; potato vs. control, $p = 0.005$). A lentil pre-exercise meal was able to deliver adequate, but not optimal, fuel for slight improvements in exercise performance. Findings from the Nutritional Knowledge Questionnaire and assessment of attitudes towards pulse-based meals did not support the fourth hypothesis; as no significant positive correlations relationships were identified between the participants' nutrition knowledge and their attitudes towards pulse-based meals. However, a strong negative correlation was observed between the average overall barrier score and weekly pulse consumption ≥ 1 serving ($r=-0.905$, $p<0.05$), perhaps indicating other factors rather than attitudinal barriers influence pulse-based meal consumption more significantly. The subjects were not strongly opposed to pulse-based meal consumption as they disagreed with the majority of the barrier statements, but unfortunately did not identify behaviours or actions to support their cognitive concepts. Generally, lentils performed similarly to the tested high glycemic index pre-exercise meals with respect to acceptability of sensory and digestive requirements, and slightly better than the other test meals for efficacy for improving sport performance. Improved acceptability and tolerability of the lentil pre-exercise meal could lead to even greater improvements in exercise performance.

5.3.1. Acceptability Requirements for Optimal Exercise Performance

In addition to the nutritional requirements of a pre-exercise meal, acceptability requirements such as a meal's ability to fulfill the sensory, familiarity, tolerability, and digestibility requirements of an athlete are important to ensure adequate energy and carbohydrate consumption for optimal exercise outcomes (Birch, 1999; Drewnowski, 1997; Lawless & Heymann, 1998). Previous research has identified a direct association between the palatability of a meal and the amount consumed; for example, Guy-Grand et al. (1994) identified a significant increased conventional meal intake when meal palatability increased. The majority of our participants were unable to consume the entire meal amounts, even when they were reduced from the initial design of the study (1.5 g CHO $\cdot$kg bw^{-1}), indicating that the manner in which our pre-exercise meals were designed or delivered did not fulfill suitable acceptability requirements, which may have prevented complete consumption. This may have affected exercise performance; however, the amounts of the meals that were consumed still produced valid performance outcomes. Several studies have investigated the effect of meal palatability on energy intake and identified a strong and consistent positive relationship (De Graaf et al., 1999; Yeomans & Symes, 1999; Zandstra et al., 2000). De Graaf et al. (1993) identified an increase in energy intake from a more palatable meal when compared to a less palatable meal; as the sweetness increased the energy intake also increased. Improved acceptability of the pre-exercise meals may have generated even stronger support of lentils, delivered with improved palatability, as an ideal fuel for athletes of high intensity intermittent exercise.

5.3.1.1. Sensory Requirements

An athlete's familiarity, knowledge or acquaintance with a food is a key requirement to ensure adequate pre-exercise meal consumption for optimal exercise performance (Rodriguez et al., 2009). This study was the first exposure of many of the participants to lentils, with all participants indicating that they consumed 1 or fewer servings of lentils per week, and 58% indicating that they consumed 1 or fewer servings of pulses weekly. The lentil meal, and the other test meals, produced unfamiliar smells, tastes, textures, flavours, and visual stimulation. The sensory evaluations of our lentil preparation and delivery were rated as "not appealing" (64%) in terms of visual appeal and flavour, with portion sizes that were rated as too "large" or "cumbersome" (cumulative 82%). The lentil meal was also rated as "not easy" (73%) to consume, with an unappealing aroma. Negative sensory perceptions observed across all test meals may have affected meal consumption amounts, respective energy and carbohydrate intakes, and possibly performance outcomes. This reinforces the importance of acceptable sensory perceptions of a pre-exercise meal to ensure complete consumption, as adequate consumption of pre-exercise nutrition improves exercise performance.

5.3.1.2. Digestive Requirements

A nutritionally sound pre-exercise meal for optimal performance should be well-tolerated by the athlete's gastrointestinal system, as post-prandial digestive symptoms, as well as symptoms during and after exercise, can affect performance outcomes (Brouns, 1991; Rodriguez et al., 2009). For instance, digestive distress can negatively affect running performance (Brouns, 1991). Adverse pre-exercise meal digestive symptoms can also affect the meal proportion consumed, and thus reduce energy intake and exercise performance (Brouns, 1991; Welsh, Davis, Burke, & Williams, 2002). In our study, the average meal consumption was 80% of the delivered amount. Incomplete consumption of the delivered pre-exercise meal amounts should have resulted in the most severe symptoms of fullness, bloating or nausea from the participants' digestive symptoms rating scale responses. Severe ratings of fullness were expected at the first two assessment points from participants who could not consume the entire portion; however, as seen in Table 5.17, the participants failed to consistently rate severe digestive symptoms during or immediately after meal consumption, clearly indicating digestive distress was not inhibiting consumption of the entire pre-exercise meal. Observed ratings of hunger symptom severity also reinforced the observation that gastrointestinal symptom severity was not the limiting factor for the amount of pre-exercise meal consumed: ‘no symptoms’ of hunger would be expected in the post-prandial period if the athletes terminated meal consumption due to physiological capacities. Increased hunger severity would be expected nearer to exercise but, oddly, some ratings of mild and moderate hunger were observed at all post-prandial time points in the fed conditions. These findings suggest that other sensory or external factors may have contributed to inadequate meal consumption in this study. All fed conditions also elicited a slight post-prandial increase in nausea, with the greatest increase in the lentil condition at the first assessment point in 2 participants. The development of nausea is often attributed to unfamiliar smells, tastes, or the consumption of a large amount of food or fluid (Brouns, 1991). Rather than nausea from overconsumption, increased symptom severity could be a result of prolonged fasting, as the body mobilizes energy and blood to the gut for improved digestion. This may further compromise other physiological functioning.

Adverse pre-exercise meal digestive symptoms experienced during exercise are far more detrimental to optimal performance than post-prandial symptoms, and exercise intensity, proficiency, and ease can be negatively affected by severe symptoms of bloating, cramping, nausea, fullness, and hunger (Brouns, 1991; Rodriguez et al., 2009; Welsh et al., 2002). Welsh et al. (2002) have previously highlighted the importance of adequate pre-exercise meal consumption to subdue severe feelings of hunger and maintain mental focus towards the end of exercise. In our study, the lentil condition may have provided a more beneficial metabolic environment for the prevention of feelings of nausea. Potential causes of nausea during exercise can be minimized with the intake of a low GI lentil pre-exercise meal via metabolic mechanisms to maintain blood sugar levels such as: the sparing of glycogen for utilization at the end of an exercise bout, improvements of insulin and glucagon blood profiles to mobilize fat for energy production during exercise, and maintenance of a steady rate of glucose absorption for a prolonged period of time (Ivy et al., 1988; Stevenson, McComb, & Oram, 2005; Wee et al., 2005; Febbraio et al., 2000; Costill et al., 1977; Sparks et al., 1988). Test conditions other than the lentil condition had increased severity of nausea in the second last and last assessment points, increasing from no symptoms to mild and moderate, while 92% of respondents reported no symptoms of nausea after consuming the lentil meal. The increase in the severity of symptoms of nausea in the other meal conditions could be attributed to depleted muscle and liver glycogen stores, low blood glucose levels, and elevated blood glucagon concentrations and resultant fat mobilization. The fibre content of the meal may also have contributed to the adverse scores observed in the test meal analysis and the digestive symptoms rating scale. The meals were all rated as "not easy" to consume, and in the majority of cases the entire designed amount was not consumed for any of the meals. A substantial fibre component also increases mastication time and may affect the participant's feelings of fullness, as internal neurological signalling during consumption can elevate feelings of fullness and prevent complete meal consumption (Welsh et al., 2002). Meal consumption may also have been limited by the increased meal volume from the high fibre content of all the meals.

While international sport nutrition recommendations promote familiarity and tolerability of pre-exercise meals to ensure satisfaction of nutritional requirements and optimal performance achievement, the meals in our study were not designed to accommodate sensory requirements, an overlooked requirement affecting consumption.

5.3.1.3. Questionnaire

Improved intake of healthy foods is positively correlated with nutrition knowledge; hence, the incorporation of the nutritional knowledge section into the pulse-based examination tool was supported (Gibson et al., 1998; Werblow et al., 1978; Zawila et al., 2003). Lentils are not commonly consumed in the Canadian population, primarily due to taste and texture (Ipsos-Reid, 2010). Identification of nutritional knowledge levels in our participants could provide information to identify consumption barriers and predict pulse or lentil consumption patterns (Ipsos-Reid, 2010). Unfortunately, the small sample size of our research design did not provide strong correlations between consumption and attitudes towards pulses, but future work with the questionnaire with larger sample sizes could reinforce the positive relationship between nutritional knowledge and healthy food consumption.

The questionnaire employed in this research study assessed the nutritional knowledge of a small group of participants, assessed the psychosocial concepts of attitudes, beliefs, and barriers towards pulse-based meal consumption, and identified the participants' dietary intake patterns of pulses and specifically lentils. As the components of this questionnaire had been previously validated (Lea et al., 2006; Zawila et al., 2003), the items were valid and reliable. However, the modification of the plant-based questionnaire of Lea et al., (2006) to a pulse-based meal investigation had not yet been employed or assessed. The small number of participants had no difficulties interpreting or responding to the modified beliefs and barriers questions, and the assessment of responses was successful.

Consumption barriers observed in other research studies were similarly observed in the responses of our participants (Bennett et al., 2012; Ipsos-Reid, 2010). An investigation by Desrochers & Brauer (2001) identified barriers to pulse-based consumption such as lack of preparation knowledge, lack of familiarity with different legumes and pulses, negative perceptions around flatulence, and lengthy preparation time. Additionally, Bennett et al. (2012) identified similar strong barriers to pulse consumption such as a lack of preparation knowledge and limited social support. Phillips (2012), also identified similar barriers to lentil consumption with the D.A.I.L.Y (Diet Approaches to Increase Lentil Consumption in Youth) administered to caregivers, such that palatability/appetite, preparation knowledge and food familiarity were the primary barriers interfering with lentil consumption. Participants in this research study strongly agreed with the barriers stating they did not know how to prepare pulse-based meals (75%), and that they needed more information about pulses (58%). Questionnaire statements investigating the preparation time or convenience of pulse-based meals produced moderate levels of negative barriers: 42% of responses indicated pulse-based meals took too long to prepare, and 33% of responses indicated pulse-based meals were inconvenient; in addition unsure responses of 25% and 33% were observed in the respective statements. In contrast, the small sample group strongly disagreed with many barriers associated with pulse-based meal consumption such as their family/partner wouldn't eat a pulse-based meal (83%), a pulse-based meal would not be filling enough (75%), or that they may not have enough will power (92%). However, despite strong disagreement with several barrier statements, the average weekly intake of pulses and or lentils was poor: 58% of participants chose pulses 2 or fewer times per week, and 100% of participants chose lentils once or less per week. This finding is also similar to findings of Phillips (2012), in that D.A.I.L.Y. participants perceived greater benefits to lentil consumption than barriers; however, like this study 58% of respondents said they "never or rarely" consume lentils.

Participants strongly agreed with many beliefs statements in the questionnaire: Strong positive belief responses ranged from 75-92% for statements assessing improved food variety, good source of protein provision, decreased intake of saturated fat, improvements in digestion, and general disease prevention. Improvements in gut health, reduced risk of cardiovascular disease, diabetes, and obesity are only some of the significant health benefits of pulse and lentil consumption (Kushi, Meyer, & Jacobs, 1999). Pulse and legume consumption 4 or more times weekly also reduces risk of coronary heart disease by 22% and reduce risk of cardiovascular disease by 11% (Nagura, Iso, Watanabe, Maruyama, Date, Totyoshima, Yamamoto, Kikuchi, Koizumi, Kondo, Wada, Inaba, Tamakoski, & JACC Study Group, 2009). Health benefits associated with lentil consumption were also assessed by Phillips, Moore, & Tnag identifying a desire to improve healthy eating patterns with increased lentil consumption (2011). A strong negative correlation was observed between the average overall barrier score and weekly pulse consumption ($r = -0.905$, $p < 0.05$), with a correspondingly strong positive correlation between overall belief score and participant agreement with the pulse-based meal benefits ($r = 0.620$, $p < 0.05$). Participants' positive beliefs towards pulse-based meals could translate into behaviours of improved pulse-based meal consumption, but a significant correlation between pulse intake and beliefs and benefits of consuming pulse-based meals was not observed. Perhaps improvements in the number and specificity of the pulse and lentil consumption questionnaire items may improve the participants' ability to identify and quantify the frequency of pulse servings in their diet, as many may not associate a food containing a pulse or legume as serving of pulses. Questionnaire items and descriptors within the items, including specific pulses and legumes or typical food items or products prepared with pulses, may improve participant understanding, interpretation, and response accuracy.

Generally, the athletes who participated in this research study had a high correlation between their athlete specific nutritional knowledge score and their general nutrition score ($r = 0.786$, $p <0.05$). As previously addressed, factors affecting an athlete's dietary choices are multifaceted with nutrition knowledge and lifestyle playing key roles (Heaney et al., 2008). A strong correlation was also observed between physical activity levels and general nutrition knowledge ($r = 0.733$, $p < 0.05$), perhaps indicating the participants have an awareness of the importance of nutrition for optimal exercise performance (Kreider et al., 2010; Rodriguez et al., 2009).

5.3.2. Nutritional Requirements for Optimal Exercise Performance

Optimal exercise performance relies heavily on the pre-exercise energy and macronutrient status of the athlete (Burke 1998a, Hargreaves, 2001; Hargreaves et al., 2004; Wee et al., 2005). As lentils have a unique macronutrient profile, we investigated these pulses for their ability to meet the specific nutritional requirements of high-intensity intermittent exercise when eaten before exercise (Rodriguez et al., 2009).

5.3.2.1. Water, Fat and Fibre

In addition to adequate water provision, optimal exercise performance was not compromised due to the fat content of the lentil pre-exercise; the lentil meal was low in fat, ≤ 4 g fat / meal, and within the limits recommended to ensure prompt gastric emptying and decreased gastrointestinal distress (Riddoch & Trinick, 1988; Brown et al., 1994; Deibert et al., 2005; Riddoch & Trinick, 1988). Indeed, our study identified few severe post-prandial digestive symptoms in response to the lentil meal, and exercise performance did not seem to be affected. However, the lentil meal and test meals provided in this study delivered more fibre than recommended, with 20 to 40 g of dietary fibre ingested per meal (0.4 g fibre/kg body weight), on average. Some studies have shown that reduced fibre content ensures quick digestion of the pre-exercise meal, which allows the prompt delivery of macronutrients into circulation and decreases the risk of gastrointestinal distress and discomfort over the post-prandial period, as well as during exercise (Brown et al., 1994; Burke, 2005; Deibert et al., 2005; Brown et al., 1994; Hansenm Knudsen, & Eggum, 1992; Riccoch & Trinick, 1988; Rodriguez et al., 2009; Deibert et al., 2005; Riccoch & Trinick, 1988). In contrast, increased dietary fibre intake improves the gastrointestinal system’s ability to absorb fluid efficiently, decreases the rate of glucose absorption, and does not affect the rate of fecal discharge (Haack, Chesters, Vollendorf, Story, & Marlett, 1998; Spiller, 1999), although it may increase fecal bulk. Interestingly, differences in the rates of digestion and absorption of high and low glycemic meals have been observed despite similar fibre contents. Reduced digestive acceptability of a lentil pre-meal may therefore be due to its low glycemic index from complex carbohydrate composition (30% amylose and 70% amylopectin), substantial protein content, and inclusion of anti-nutrient compounds (Thorne et al., 1983) rather than the high fibre content, as the aforementioned traits also can cause severe digestive symptoms (Thorne et al., 1983).

5.3.2.2. Glycemic Index

The glycemic response that results from the consumption of a pre-exercise meal can affect substrate oxidation in the post-prandial period, as well as throughout an upcoming exercise bout (Mondazzi & Arcelli, 2009). Specifically, high glycemic index pre-exercise meals increase carbohydrate dependency during exercise and consequently increase the rates of carbohydrate oxidation and endogenous glycogen utilization (Febbraio et al., 2000; Wee et al., 1999; Wee et al., 2005; Wee et al., 1999; van Loon et al., 2001). However, a low glycemic index pre-exercise meal may preserve glycogen for the latter portion of exercise, and increased muscle glycogen leads to improved power (Balson et al., 1999; Maughan, 1988), optimal skeletal muscle contractile performance (Shulman & Rothman, 2001), and maintenance of blood glucose for uncompromised central nervous system functioning (Hargreaves, Costill, Katz, & Fink, 1985; Winnick, Davis, Welsh, Carmichael, Murphy, & Blackmon, 2005). In this study as reported by Little et al., (2010), the blood glucose concentrations measured after the consumption of the two high GI potato meals were significantly higher compared to those measured after the consumption lentil and control conditions throughout the post-prandial period (15, 30, and 60 minutes following pre-exercise meal consumption) ($p< 0.001$). The GI of the lentil pre-exercise meal, more so than the potato meals, may have contributed to improved exercise performance via lower post-prandial blood glucose concentrations, lower serum insulin response during exercise, and greater fatty acid oxidation during exercise. Pre-exercise meals that produce a high insulin response inhibit lipolysis, stimulate lipogenesis, and decrease the concentration of free fatty acids in circulation post-meal, as well as through the subsequent exercise bout (Brodski IG, 2006; Febbraio et al., 2000; Mondazzi & Arcelli, 2009; Trenell et al., 2008; Wee et al, 1999; Wee et al., 2005). This produces a metabolic environment that increases reliance on carbohydrates for energy production and decreases exercise performance (DeMarco et al., 1999; Siddossis et al., 1996; Thomas et al., 1991; Wee, 1999; Wee et al., 2005; Wu & Williams, 2006).

Adequate total energy intake has been hypothesized to be more influential for optimizing muscle glycogen stores than the glycemic response of a pre-exercise meal or glycemic index of the carbohydrates consumed in the days before exercise (Burke et al., 1993; Burke et al., 2005; Jentjens & Jeukendrup, 2003; Kochan et al., 1979; Stevenson et al., 2005). However, if the expedited recovery of glycogen stores is required for an upcoming bout of exercise in the same day, the amount and type of carbohydrate consumed should be considered for optimal glycogen replenishment. Burke et al. (2005) found that a high GI post-exercise meal was more beneficial for glycogen replenishment than low or moderate GI meals consumed in the first 24 h of recovery. Contrarily to a high GI pre-exercise meal which quickly raises and lowers blood glucose concentration, low GI carbohydrate choices pre-exercise facilitate consistent provision of glucose into the blood which is key for glycogen replenishment (Jenkins et al., 1983; Mondazzi & Arcelli, 2009; Rodriguez et al., 2009). The consumption of a low GI pre-exercise meal has been proposed to positively affect exercise performance and metabolism due to specific biochemical and functional mechanisms: lower blood glucose and insulin levels, decreased suppression of plasma free fatty acids, higher rates of fat oxidation, lower rates of carbohydrate oxidation, and the extended availability of glucose sources (DeMarco et al., 1999; Mondazzi & Arcelli, 2009; Siddossis et al., 1996; Thomas et al., 1991; Wee et al., 1999; Wee et al., 2005; Wu et al., 2003; Wu & Williams, 2006). Lentils are therefore not only advantageous as an ideal pre-exercise fuel, but should be considered an excellent addition to an athlete's general diet due to their ability to maximize glycogen stores and ensure the prolonged and constant availability of exogenous carbohydrates for glycogen preservation (Chryssanthopoulos et al., 2004; Wee et al., 2005; Tsintzas, Williams, Boobis, Greenhaff, 1995; Tsintzas, Williams, Boobis, Greenhaff, 1996; Wee et al., 2005).

5.3.2.3. Carbohydrate

The carbohydrate component of lentils may be the most influential factor when considering this pulse as the ideal pre-exercise meal for optimal sport performance (Hargreaves, 2001; Hargreaves et al., 2004; Jeukendrup & Gleeson, 2004; Williams & Serratosa, 2006). The lentil meal in this study delivered high-quality, slow-digesting carbohydrates that produced an improved post-prandial blood glucose profile compared to the other test meals. The enhancement of performance due to pre-exercise carbohydrate consumption has been attributed to several metabolic mechanisms, including increased hepatic gluconeogenesis during exercise (Trimmer et al., 2002), the preservation and replenishment of endogenous glycogen stores (Chryssanthopoulos et al., 2004; Wee et al., 2005; Tsintzas et al., 1995; Tsintzas et al., 1996; Wee et al., 2005)), and decreased reliance on glycogen in type 1 muscle fibres (Bosch et al., 1994; Coyle et al., 1986; De Bock et al., 2007; Hargreaves & Briggs, 1988; Jeukendrup &

Wallis, 2005; De Bock et al., 2007). Together, these mechanisms act to maintain carbohydrate oxidation in working muscle toward the latter portion of an exercise bout. The availability of such a prolonged exogenous carbohydrate supply from slow digesting amylopectin in lentils (Shahen, Roushdi, & Hassan, 1977) has also been shown to decrease glycogen depletion, maintain the levels of plasma glucose, and enable optimal central nervous system functioning and mood during an exercise bout (Bangsbo et al., 2007; Burke et al., 2005; Coyle et al., 1986; Hargreaves et al., 1985; Mohr, Krustrup, & Bangsbo, 2005; RicoSanz, Zehnder, Buchli, Dambach, & Boutellier, 1999; Williams & Serratosa, 2006; Winnick et al., 2005). However, the aforementioned mechanisms mentioned above are only maximized when athletes consume an adequate carbohydrate-rich meal containing 140-300 g available carbohydrate 3–4 hours prior to exercise (Hargreaves, 2001; Hargreaves et al., 2004; Jeukendrup & Gleeson, 2004; Rodriguez et al., 2009; Williams & Serratosa, 2006), as well as adequate amounts of energy and carbohydrate in the days prior to exercise. Athletes consuming 6-10 g CHO/kg bw per day have a greater probability of maximizing the aforementioned performance enhancing mechanisms, and tend to avoid reduced training benefits and inhibited exercise performance due to limited muscle glycogen (Rodriguez et al., 2009; Kreider et al., 2010). On average, our participants consumed 5.8 g ± 1.4 g CHO·kg $bw^{-1}·day^{-1}$, with a range of 4.2 g to 8.8 g CHO·kg $bw^{-1}·day^{-1}$ (Table 5.22), which falls below the amount of carbohydrate recommended for optimal exercise performance. The research participants, on average, did not consume adequate amounts of carbohydrate in the day prior to exercise, and may have entered exercise testing with submaximal endogenous glycogen stores and increased risk of fatigue. The progressive decline of endogenous glycogen during exercise increases the energy dependence on blood glucose (Coggan & Coyle, 1991). When no exogenous or serum carbohydrate is available and endogenous carbohydrate stores are limited, energy metabolism shifts from efficient aerobic carbohydrate oxidation to inefficient fat oxidation, and energy production becomes inadequate for optimal performance, leading to fatigue (Bergstrom et al., 1967; Hawley et al., 1994; Krogh & Lindhard, 1920; Nybo, 2003). Despite our participant's inadequate energy and carbohydrate provision from both daily and pre-exercise meal intake the lentil meal, prior to sprint testing, as per the research of Little et al., (2010), preserved the greatest amount of muscle glycogen throughout exercise compared to all other experimental conditions.

5.3.2.4. Protein

Excellent carbohydrate content is not the sole attribute of lentils that lend them to being the ideal pre-meal for high intensity intermittent athletes, as they are also a high source of protein. In this study, the athletes were supplied with approximately 0.9 grams of protein/kg body weight, which conforms to the recommendations of international sport nutrition regulatory bodies that pre-exercise meals should provide moderate protein amounts (Rodriguez et al., 2009; Kreider et al., 2010; Rodriguez et al., 2009). An ideal pre-exercise meal of moderate protein content enhances endurance performance (Ivy et al., 2003, Saunders, Kane, & Todd, 2004), and may alter the insulin or glycemic response through the facilitation of glucose disposal (Betts et al., 2005; Walton & Rhodes, 1997; Spiller et al., 1987). Several mechanisms have been theorized to explain the effects of protein content on metabolism and exercise performance; however, no single mechanism has yet been identified (Ivy et al., 2003; Gleeson, 2005; Romano-Ely et al., 2006; Saunders et al., 2004). In consideration of the aforementioned attributes, the lentil pre-exercise meal adheres to international recommendations for pre-exercise meal protein content required to maintain nitrogen balance, improve glucose disposal, and reduce feelings of hunger; hence, lentils may be an ideal pre-exercise meal for athletes of high intensity intermittent exercise to achieve optimal exercise performance outcomes (Kreider et al., 2010, Betts et al., 2005; Welsh et al., 2002).

5.3.2.5. Exercise Performance

An athlete's optimal exercise performance is specific to the exercise type, and depends on the ability of the athlete to perform free of fatigue or detrimental physiological conditions such as decreased blood glucose levels (Bergstrom et al., 1967; Hawley et al., 1994; Nybo, 2003). Specifically, fatigue experienced toward the end of a soccer trial can most likely be attributed to the depletion of stored carbohydrate rather than decreased carbohydrate availability in the blood (Leatt & Jacobs, 1989; Mohr, Krustrip, & Bangsbo, 2003; Mohr et al., 2005; Saltin, 1973). Average total sprint distances between the three fed experimental conditions were similar, while each total sprint distance for lentil, potato & egg, and potato meals were greater than control ($p<0.05$). The pre-exercise meals delivered in this research study were not significantly different than one another regarding exercise performance; however, the lentil meal did produce slightly greater sprint distances in the first two sprints of the repeated sprint tests as per Little et al., 2010.

This study also assessed the relationship between optimal performance and energy and carbohydrate intake using an overall performance score for each participant to investigate the effects of energy and carbohydrate intake on sport performance. A moderate correlation was observed between overall performance score and the total energy consumed (24 h + pre-meal), whereby distance covered (OPS) increased in a positive linear fashion with increased energy intake in the day prior to exercise testing. This suggests the baseline endogenous carbohydrate stores from the 24-72 hours prior to exercise influenced the distance covered in the repeated sprint tests (Rodriguez et al., 2009). Our results reinforce the importance of pre-exercise energy and carbohydrate intake in the 24 hours and immediately prior to exercise as significant differences between high and low energy and carbohydrate intake groups were observed for overall sport performance ($p<0.05$). As no significant differences were observed between the high and low intake groups for pre-exercise meal energy and carbohydrate we can suggest our participants' 24 h food intake influenced their sport performance more than the pre-exercise meal alone.

On average the participants in the high intake group for pre-exercise total carbohydrate intake consumed 1.2 ± 0.2 g·kg^{-1}, and with adjustments for dietary fibre amounts the athletes consumed ~1.0 g available CHO·kg^{-1}. This carbohydrate intake amount does not meet recommended standards for performance improvements after a 2 hour post-prandial period. However, despite inadequate carbohydrate intake many participants consumed > 8.0 kcal·kg^{-1} from the pre-exercise meals, which provided similar energy intake to a pre-exercise meal designed to deliver 2.0 g CHO ·kg^{-1}. Perhaps the increased lentil meal protein content provided ample fuel, in the absence of adequate available carbohydrate, to match the recommended energy requirements for improvements in exercise performance. Optimal performance outcomes depend on the pre-exercise meal to entirely fulfill requirements, as well as adequate daily nutrition to facilitate endogenous glycogen preservation and replenishment (Burke et al., 2005; Chryssanthopoulos et al., 2004; Hargreaves, 2001; Tsintzas et al., 1995; Tsintzas et al., 1996; Wee et al., 2005). Although this research study has not fully elucidated the ideal pre-exercise meal for optimal performance, many aspects of an ideal pre-exercise meal have been determined (Little, Chilibeck, Bennett, & Zello, 2009). Little, et al., (2009) state that a slow digesting low GI carbohydrate source which yields a minimal insulinemic response may be an optimal pre-exercise meal; as carbohydrate intake, especially that of high GI, promotes an increase in circulating insulin, reduction of fat oxidation, increase in carbohydrate oxidation, and resultant muscle glycogen depletion. Slow digesting, low GI lentils as part of daily dietary intake patterns or pre-exercise nutrition for athletes of high intensity intermittent exercise could provide adequate carbohydrate, ideal protein, ample energy and lead to metabolic environments ideal for optimal exercise performance.

CONCLUSIONS & RECOMMENDATIONS

6.1. Summary and Conclusions

The primary objective of this research study was to investigate lentils as an ideal pre-exercise meal for athletes of high intensity intermittent exercise such as soccer players. Four experimental conditions were employed to investigate this objective: lentil (low GI high protein), potato (high GI low protein), potato & egg (high GI high protein), and control, which were delivered prior to a treadmill-based simulated soccer trial. Nutritional and acceptability requirements of a low glycemic index lentil pre-exercise meal for athletes of high intensity intermittent exercise were assessed with sensory and gastrointestinal variables, and performance outcomes to investigate the first objective. Additionally, a questionnaire investigating nutritional knowledge and attitudes towards lentils and pulse-based meals in male athletes was employed in the second objective.

Assessment of both the nutritional and acceptability requirements produced several key findings supporting further investigation of lentils as part of an acceptable pre-exercise meal for improved performance. Pre-exercise meal acceptability measured by meal consumption was fair as all the experimental conditions were accepted similarly at 79.5 % consumption. Improvements in the participants' consumption amounts would be ideal for the delivery of adequate energy and macronutrients for optimal sport performance, but even with the slightly compromised consumption amounts, the lentil meal was able to produce improved performance outcomes. With respect to the acceptability requirements of the pre-exercise meals, the lentil meal was similar to the high GI high protein potato & egg meal with regards to gastro-intestinal digestive requirements and sensory acceptance. The lentil meal had the least severe ratings of hunger toward the end of exercise when compared to the potato and potato & egg meals, and elicited lower ratings of abdominal cramping at 90 and 105 minutes compared to the potato meal. Ratings of nausea at 90 and 105 minutes were similar in the control, potato, and potato & egg conditions, indicating that the physiological environment influencing neurological functioning may have been similar in those three conditions, while the reduced levels of nausea reported at the end of exercise following the consumption of the lentil meal may have been due to increased fuel availability. The lentil meal produced similar total sprint distances as the high glycemic test conditions, and each fed meal condition generated a total sprint difference greater than control ($p<0.05$). An assessment of energy and carbohydrate intake effects on overall performance scores found significant correlations between total energy (24 h + pre-meal), pre-exercise meal energy, and pre-exercise meal carbohydrate intake and improved overall performance ($p<0.05$). Improvements in overall performance scores were also observed when the participants had greater total energy intake ($kcal \cdot kg\ bw^{-1} \cdot day^{-1}$) and greater total carbohydrate intake ($g \cdot kg\ bw^{-1} \cdot day^{-1}$) compared to participants with lesser intake amounts ($p<0.05$). Additionally, Little et al., (2010) showed that the lentil meal produced a lower post-prandial glycemic response and lower pre-exercise insulinemic response than the potato meal (high GI low protein). The potato meal also resulted in significantly higher rates of carbohydrate oxidation and lower rates of fat oxidation than control throughout exercise. In conclusion, the lentil meal produced similar negative and positive results of hunger, fullness, nausea, bloating, and headache when compared to the potato & egg meal. Any statistically significant differences in these parameters were minimal, and were most often observed between the other conditions. Fullness may not have been the most influential factor limiting complete meal consumption, and perhaps enhanced lentil meal appetite and palatability improved consumption would be observed. The negative sensory perceptions of the pre-exercise meals may have contributed to the insufficient meal consumption amounts rather than the experienced gastrointestinal symptoms during and following meal consumption. Furthermore, while the fibre content of the meals may not have affected consumption, the difficulty of ingestion may have been detrimental to meal completion. The red football lentils required more mastication for ingestion compared to the instant mashed potatoes, and perhaps triggered satiety cues preventing complete pre-exercise meal consumption. Alterations in the lentil processing grade, reducing mastication time while maintaining the unique macronutrient profile, or reducing pre-exercise meal fibre content may be viable methods to improve lentil pre-exercise meal acceptability and completion.

This research employed the ‘Nutritional knowledge and attitudes towards a pulse-based diet questionnaire’ to complete the second objective and investigate the fourth hypothesis: higher nutrition knowledge positively influences attitudes of lentils and pulse-based meals. The examination tool investigating nutrition knowledge, psychosocial concepts influencing pulse and lentil consumption, and participant demographics provided adequate information the participants’ nutritional knowledge and attitudes towards pulse-based meals. Future investigations may find the employment of this questionnaire ideal for assessing nutritional knowledge and attitudes beliefs and barriers towards pulse-based meals in athletic and non-athletic populations. Nutritional knowledge and demographic information provided an accurate assessment of the research participants, but only weak correlations were observed between the nutritional knowledge or demographics and pulse or lentil consumption patterns. A strong negative correlation was observed between weekly pulse consumption and average barrier score, while a strong positive correlation was observed between overall belief score and participant agreement with the benefits associated with pulse-based meals. Generally, the participants were open-minded to increasing pulse consumption; however, barriers of meal preparation and a lack of pulse and lentil knowledge may be influencing observed low consumption ratings.

Improved performance outcomes were observed across all conditions when the participants had improved total energy and carbohydrate intake, and the highest overall performance score was directly correlated with the highest total energy and carbohydrate consumption. The participants’ ratings of perceived exertion, as reported by Little et al. (2010), while completing the lentil condition produced the lowest results, indicating that the lentil meal may have prevented fatigue by increasing fuel availability. Lastly, as shown by Little et al., (2010) the lentil meal also produced the highest levels of muscle glycogen stores, which has been show to improve performance (Krieder et al., 2010; Rodriguez et al., 2009) and result in ideal substrate utilization and decreased fatigue. The aforementioned outcomes validate the further investigation of the applicability of lentils, perhaps as a sports bar or cereal product, as a viable pre-exercise meal for high-intensity intermittent exercise athletes.

6.2. Limitations and Future Directions

While we demonstrated in this study that lentils are a beneficial pre-exercise meal for athletes, we were unable to concretely identify lentils as the ideal fuel for athletes of high-intensity intermittent exercise due to limitations in our experimental design and research conditions. As mentioned by Little et al., 2009, future research involving optimal pre-exercise nutrition, specifically for intermittent sport, should focus on meals of various glycemic indices on muscle glycogen utilization to highlight the benefits of low GI carbohydrate consumption as an optimal fuel source. Greater consistency in research outcomes in future investigations could be achieved with improved meal design to ensure adequate consumption according to international sport nutrition recommendations. Consistent measurement of post-prandial physiological parameters would also enable future investigations to elucidate metabolic differences between high and low glycemic meals with or without substantial protein content. Improved physiological measurements would also enable the assessment of differences in macronutrient metabolism between various levels of athletic conditioning, as elite level conditioning enables improved glucose disposal and requires a greater total amino acid pool.

Sensory and gastrointestinal acceptability requirements should also be improved upon in future investigations that examine the effects of pre-exercise meals on performance outcomes, as greater consumption, adherence, digestion, tolerance and participation from participants may be observed if the palatability of the meal were improved. Improvements in lentil preparation methods may lead to improved consumption; a reduction in water could be employed to improve the texture of the lentils. When the lentils were prepared 3 parts water to 1 part dry lentils the cooked product became mushy and the lentils lost their brilliant red colour. Measures to improve and perfect the colour and visual appeal of the lentils could improve consumption. Microwave or stovetop cooking at 2 or 2.5 parts water to 1 part lentils would improve appearance and generate an al dente texture. The taste of the lentils would also require improvements to increase consumption amounts; perhaps, the addition of familiar savour spices typically used with lentils preparation such as a classic Indian curry, or lentil-style hummus spread. Incorporation of lentils into familiar food products may also be an appropriate method to utilize the ideal macronutrient profile of lentils for athlete nutrition; some typical foods may be quick breads like banana or zucchini loaves, muffins, yeast-leavened breads, pasta, dips, soups, dry cereals, and hot cereals.

Stimulating increased national pulse consumption was a strong component in the rationale of this research study as well as the research studies recently performed by this and other research groups (Bennett et al., 2009; Little et al., 2010; Phillips, 2011). The findings of this investigation highlight the participants' willingness to consume pulse-based meals, as also observed a related study employing the same questionnaire (Bennett et al., 2009). However, several barriers interfere with the culmination of the behaviour such as a lack of knowledge regarding pulses and way to prepare them. Alterations in the cognitive barriers associated with reduced pulse consumption need to be altered to see changes in the observed consumption patterns, and perhaps educators can play a role in changing these negative cognitive concepts early on in life. Grade school educators may employ several mechanisms such as field trips to observe pulse crops or providing already existing pulse-based snacks (e.g. hummus & crackers/vegetables, roasted chickpea snacks, roasted/fried whole pea snacks, lentil crackers, and black bean salsas) to positively introduce students to lentils and other pulse-based foods. At a secondary education level, educators could incorporate pulse knowledge and application components into Wellness, or Home Economics curriculum; highlighting the environmental, nutritional, and health benefits, and culinary applications of lentils could only improve cognitive perceptions. Instructing students on ease of preparation and convenience of canned hydrated pulses could only work to forge positive beliefs and practices toward pulse-based foods, and improve national lentil and pulse consumption. Along with the added diversity the students would experience in their diets they would also benefit from the wide range of health benefits associated with lentils and other pulses.

Consistency in optimal performance outcomes would also be achieved with improved regulation and optimization of muscle glycogen levels at the beginning of exercise. Providing participants with an ideal macronutrient balance and energy provision, including consistent provision of carbohydrate (6-10 $g \cdot kg\ bw^{-1} \cdot day^{-}$) 24 hours prior to testing would have ensured athletes entered testing days with saturated glycogen stores before the pre-exercise meal. Additionally, exercise performance in human testing is often altered by issues of motivation, boredom, drive, mood, and effort. Perhaps future research into these factors could identify alternative or improved mechanisms to consistently motivate participants, such as rewards or other positive reinforcements.

The sensory and digestive acceptability of a low GI lentil pre-exercise meal was similar to high GI pre-exercise experimental meals: average meal consumption for all three test conditions was 79.5 % ($p < 0.05$). The nutritional aspects of the designed lentil pre-exercise meal adequately adhered to international exercise nutrition recommendations and allowed for provision of the ideal carbohydrate to protein ratio as a whole food. Consumption of the low GI high protein lentil meal generated a suitable metabolic condition for improved exercise performance when consumed in amounts necessary to provide > 9.0 kcal$\cdot$kg^{-1} per pre-exercise meal provision. Pre-exercise meal carbohydrate intake greater than 1.0 g$\cdot$kg^{-1}was also significantly correlated to improvements in overall performance scores. Greater energy consumption in the 24 hours before exercise testing was also correlated to improvements in distance covered as the overall performance score; and, as lentils are a nutrient and energy dense fuel, their consumption as part of a dietary regime could lead to improved athletic performance. The primary objective of this research study was to develop a low glycemic lentil pre-exercise meal for soccer trials employing four specific aims to achieve the objective. The observed acceptability and sensory perceptions of a lentil pre-exercise meal were similar to a similar potato & egg meal, but importantly the outcomes provided crucial information for the improvements of the pre-exercise meal for improved consumption. The digestive tolerability of the lentil pre-exercise meal during the post-prandial period was slightly less than the other pre-exercise meals. Detrimental digestive symptoms from the lentil meal were not observed during exercise; hence, exercise performance was not impaired. Pre-exercise meal energy and carbohydrate intake were found to have a positive linear relationship with overall performance score as greater intake led to greater distance scores. The effects of total energy intake and total carbohydrate intake on overall sport performance was also significant as main effect of high intake on overall performance score was observed for each variable. An optimal pre-exercise lentil meal for athletes of high intensity intermittent exercise would fulfill all nutritional, sensory, and gastrointestinal requirements to enable consumption of the recommended macronutrient amounts and improve exercise performance. Participants of this research study experienced improved overall exercise performance following consumption of a lentil pre-exercise meal providing adequate energy and carbohydrate amounts. Despite low weekly intake of lentils and pulse-based meals, the participants did not possess overall strong cognitive attitudinal barriers to pulse consumption indicating a willingness to incorporate lentils and pulses into their dietary patterns. The unique carbohydrate-protein-lipid-profile, in addition to slight improvements in sensory requirements and palatability, lend lentils to be an ideal vehicle to deliver fuel to athletes for optimal high intensity intermittent exercise performance.

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APPENDIX 1

Confirmation of Ethical Approval

A1.1. Biomedical Research Ethics Board Certificate of Approval

UNIVERSITY OF SASKATCHEWAN

Biomedical Research Ethics Board (Bio-REB) 13-Nov-2006

Certificate of Approval

PRINCIPAL INVESTIGATOR	DEPARTMENT	Bio #
Philip D. Chilibeck	Kinesiology	05-198

INSTITUTION(S) WHERE RESEARCH WILL BE CARRIED OUT
College of Kinesiology
105 Gymnasium Place
Saskatoon SK S7N 5C2

SUB-INVESTIGATOR(S)
Gordon A. Zello, Albert A. Vandenberg, Maureen G. Reed, Huw Rees, Heather Sirounis

STUDENT RESEARCHER(S) Jonathan Little, Dawn Ciona

SPONSORING AGENCIES
SASKATCHEWAN PULSE GROWERS

TITLE
The Effects Of High And Low Glycemic Index Meals On Soccer Performance

ORIGINAL APPROVAL DATE	STUDY APPROVAL EXPIRY
16-Dec-2005	30-Nov-2007

APPROVAL OF

- Addition of M.D. for collection of muscle biopsies (Dr. Heather Sirounis)
- Addition of a student researcher (Dawn Ciona)
- Change in the title of the consent form.
- Change in one of the meal conditions
- Change in the timing of the meals given before the exercise test.
- Elimination of the test of motor unit recruitment
- Research Participation Information and Consent Form Version 4 (02-Nov-2006)
- Addition of questionnaire about how subjects feel after consuming their meals and about general dietary practices

APPROVED ON
13-Nov-2006

CERTIFICATION

The study is acceptable on scientific and ethical grounds. The principal investigator has the responsibility for any other administrative or regulatory approvals that may pertain to this research study, and for ensuring that the authorized research is carried out according to governing law. This approval is valid for the specified period provided there is no change to the approved protocol or consent process.

FIRST TIME REVIEW AND CONTINUING APPROVAL

The University of Saskatchewan Biomedical Research Ethics Board reviews above minimal studies at a full-board (face-to-face meeting. Any research classified as minimal risk is reviewed through the delegated (subcommittee) review process. The initial Certificate of Approval includes the approval period the REB has assigned to a study. The Status Report form must be submitted within one month prior to the expiry date that appears on the current Certificate of Approval. The researcher shall indicate to the REB any specific requirements of the sponsoring organizations (e.g. requirement for full-board review and approval) for the continuing review process deemed necessary for that project. For more information visit http://www.usask.ca/research/ethics_review/#.

REB ATTESTATION

In respect to clinical trials, the University of Saskatchewan Research Ethics Board complies with the membership requirements for Research Ethics Boards defined in Division 5 of the Food and Drug Regulations and carries out its functions in a manner consistent with Good Clinical Practices. This approval and the views of this REB have been documented in writing.

APPENDIX 2
Consent Forms

A2.1. Consent form

Research Participant Information and Consent Form

Title: The effects of high and low glycemic index meals on soccer performance.

Sponsor: Saskatchewan Pulse Growers

Names of Researchers: Principal Investigator: Philip D. Chilibeck, Ph.D., College of Kinesiology, University of Saskatchewan, phone: 966-1072 or 343-6577, Co-investigators: Jonathan Little, B.Sc. (student researcher, supervised by Phil Chilibeck), College of Kinesiology, University of Saskatchewan, phone: 966-1123, Gordon Zello, Ph.D., College of Pharmacy and Nutrition, University of Saskatchewan, phone: 966-5825, Dawn Ciona, B.Sc., (student researcher, supervised by Gordon Zello), phone: 966-5831, Albert Vandenberg, Ph.D., Department of Plant Sciences, University of Saskatchewan, 966-8786, Dr. Heather Sirounis, phone: 652-1211, Dr. Huw Rees, M.D., 610 Queen St., 244-4433.

Introduction: You are being invited to participate in a research study because we want to compare the effectiveness of consuming different meals (i.e., lentils, white bread, potatoes, egg whites) on running performance that simulates a soccer game.
Before you decide, it is important for you to understand what the research involves. This consent form will tell you about the study, why the research is being done, what will happen to you during the study and the possible benefits, risks and discomforts.
If you wish to participate, you will be asked to sign this form. Your participation is entirely voluntary, so it is up to you to decide whether or not to take part in this study. If you do decide to take part in this study, you are free to withdraw at any time without giving any reasons for your decision and your refusal to participate will not affect your relationship with university instructors, your academic evaluations, or any other services at the university. Please take time to read the following information carefully and, if you choose, discuss it with your family, friends, and doctor before you decide.

Purpose of the study: The purpose of the study is to compare the effectiveness of a lentil meal (i.e. boiled lentils) to potato meals (i.e. potato, white bread and egg whites or potato and white bread) for improving running performance that simulates a soccer match on a treadmill. Lentils are digested more slowly in the body than potatoes and therefore may provide energy to your exercising muscles for a longer period of time. In our study we will be comparing lentils to a potato, white bread and egg white meal, a meal of potato and white bread, and a condition where no food is consumed before a treadmill running test. We will also be comparing the effectiveness of consuming these meals on recovery from the running test. A total of 20 participants will be involved in this study.

Possible benefits of the study: Information from this study can be used by soccer players and coaches to increase endurance performance during soccer matches. These benefits are not guaranteed.

Procedures:

If you agree to be in this study the following will happen:

You will initially be given a questionnaire (the physical activity readiness questionnaire) which assesses whether you are at a health risk from participating in exercise. If there are possible health risks, with your permission we will send an additional form to your family physician for approval to allow you to participate in the study.

The study involves a total of 10 visits to our lab. The procedures to be done at each visit are as follows:

<u>Visit #1:</u>

You will have your maximal aerobic capacity determined on a treadmill test. This test determines your aerobic fitness. The length of this test can vary from about six minutes to 15 minutes, depending on your level of physical fitness. The test begins with running at an easy pace on the treadmill. The treadmill's speed is increased every minute (i.e. the treadmill gets faster and faster). This is done until you reach exhaustion. During this test you will be breathing through a mouthpiece connected to a computer that measures your maximal oxygen consumption. The maximal oxygen consumption is used to determine your level of physical fitness.

<u>Visit #2:</u>

At least 24 hours after visit #1, you will perform a "practice run" of the simulated soccer match on the treadmill. The speeds on the treadmill will vary to match the speeds you run/jog/walk during a soccer match. This will involve 5-10 second intervals of running alternating with 60 to 120 second intervals of walking or jogging. These intervals will be alternated for 45 minutes (simulating the first half of a soccer game). You will then be given a 15 minute break (simulating a half time break in a soccer game). After the break, you will continue doing the treadmill exercise (i.e. alternating intervals of running with walking/jogging) for 30 minutes. For the final 15 minutes of the treadmill test (simulating the final 15 minutes of a game) you will be required to run for 5 intervals of 1 minute, alternating with walking for 2.5 minutes. The 1 minute intervals will be done at your own pace and we will measure the amount of "distance" you cover. You should attempt to go at the fastest pace you can for each of the five 1 minute intervals during the last 15 minutes of the treadmill test.

<u>Visits #3 and #4:</u>

At least one week after visit #2, you will return to the lab for visit #3. You will be required to fast for at least eight hours prior to visit number 3. For two days prior to visit number 3 you will be required to keep a diary of all the food you consume and the amount of physical activity you perform. During these two days you will not be allowed to consume any meat products (including red meat, poultry and fish). The reason for this is that consumption of meat products affects one of the measurements we will be doing during this visit.

For this visit you will be randomized (by chance by a computer) to one of four meal conditions: 1) A lentil meal; 2) a potato, white bread, and egg white meal; 3) a potato and white bread meal; or 4) you will not receive a meal.

You will consume 250 grams of the meal once you arrive at the lab, after the eight hour fast. Two hours after you finish the meal you will perform the exact simulated soccer match on the treadmill that you performed during visit #2. You will be allowed to consume as much water as you wish during this test. After the simulated soccer match you will be provided with another 250 grams of the meal, which you will be required to eat over the next 2 hours after you leave the lab. You will be allowed to drink as much water as you want during this 2 hour period. You will be asked to record other foods that you eat for the rest of the day.

During the treadmill test the following measurements will be made:

- Approximately 10 mL of blood will be drawn from a catheter that is inserted into a vein at the top of your hand. This will be done at the start of the test and every 15 minutes during the test (for a total of 80 mL of blood). The purpose of the blood collection is to measure fats and carbohydrates so we can estimate the type of fuel sources that are being made available to your muscles.

- You will be required to breathe into a mouthpiece that feeds into a tube connected to a computer for 8-minute periods starting at minutes 3, 33, and 78 of the test.. The gases that we collect during this test (i.e. the oxygen you consume and the carbon dioxide you exhale) will be used to estimate the proportion of fat and carbohydrate your muscles are using during the exercise test.

- Every 15 minutes of the test (i.e., immediately before the blood samples are drawn) you will be asked to rate how the exercise feels on a scale of one to twenty, with "one" being "easy" and "twenty" being "very hard".

- Before the final 15 minutes of running/jogging on the treadmill (i.e. the portion of the test that is done at your own pace) a muscle biopsy will be taken from your quadriceps (i.e. the large muscle at the front of your thigh). This procedure is done under local anesthetic, which will be injected into your thigh. A small incision will be made through your skin (approximately 1 cm long). A biopsy needle will be inserted into the incision and into the mid-portion of your thigh muscle to extract a small piece of muscle. This will allow us to measure the amount of glycogen in your muscle. "Glycogen" is the main storage form of carbohydrate in your muscle and it is thought that endurance performance depends on the level of glycogen in your muscle. Dr. Huw Rees, M.D. or Dr. Heather Sirounis, will be doing the biopsy procedure. A "butter fly" bandage will be applied after the biopsy so that the incision is covered during the final 15 minutes of running/jogging on the treadmill.

After the treadmill test, the following measurements will be made:

- We will require you to collect urine in a plastic container for 24 hours after the test and return this to us the next day. We want to measure a marker for muscle protein breakdown in the urine to assess your muscles' ability to recover from the treadmill test. Meat consumption affects the level of this marker; therefore, you will not be allowed to consume meat (i.e. red meat, poultry, and fish) for two days before the treadmill test and for 24 hours after the treadmill test.

– When you return your urine container we will perform an exercise test on one of your legs that requires you to do 50 knee extensions with maximal effort on a device that measures your force output. This test lasts about one minute. The purpose of this test is to measure how well your leg muscles have recovered from the treadmill test from the previous day.

Visits #5 and #6

At least one week after visit #4, you will come back to the lab for a repeat of the testing described for visits #3 and #4, but this visit will involve a different meal condition (i.e. randomly assigned from the remaining three meal conditions) and a different leg will be biopsied. For two days before this visit, you will be required to consume the same foods and perform the same physical activities you recorded during the two days prior to visit #3. During the treadmill test you will be given the same amount of water that you consumed during the treadmill test you performed at visit #3. You will not be allowed to consume meat for two days prior to visit #5 and for 24 hours after this visit.

Visits #7 and #8

At least one week later you will again repeat the testing described for visits #3 and #4 but with a different meal condition than visits #3 and #5 (i.e. randomly assigned from the remaining two meal conditions) and a different leg will be biopsied. For two days before this visit, you will be required to consume the same foods and perform the same physical activities you recorded during the two days prior to visit #3. During the treadmill test you will be given the same amount of water that you consumed during the treadmill test you performed at visit #3.You will not be allowed to consume meat for two days prior to visit #7 and for 24 hours after this visit.

Visits #9 and #10

At least one week later you will again repeat the testing described for visits #3 and #4 but with a different meal condition than visits #3, #5, and #7 (i.e. lentil, mashed potato and white bread, mashed potato with egg whites and white bread, or no meal) and a different leg will be biopsied. For two days before this visit, you will be required to consume the same foods and perform the same physical activities you recorded during the two days prior to visit #3. During the treadmill test you will be given the same amount of water that you consumed during the treadmill test you performed at visit #3.You will not be allowed to consume meat for two days prior to visit #9 and for 24 hours after this visit.

We give you a questionnaire about how you feel (e.g., fullness, taste) when you are consuming the different test meals. Following the study we will give you a questionnaire about your general dietary practices.

Foreseeable risks, side effects or discomfort:

The exercise may result in muscle pulls or strains. You will be given a proper warm-up prior to exercising and this will minimize this risk and all exercise tests will be administered by qualified exercise trainers. If any serious pulls or strains occur, you will be withdrawn from the study.

Exercise on an empty stomach (i.e. during the “no meal” condition) may be quite fatiguing and may result in you feeling faint. You will be monitored closely during the exercise test so if this happens the test will be immediately stopped.

There may be some discomfort/pain during the drawing of blood, the muscle biopsy, or the electrical stimulus used to get a maximal contraction of the calf muscle. The discomfort during the biopsy will be minimized by giving a local anesthetic before the biopsy. There is a risk of bruising and infection with the drawing of blood and the muscle biopsy, but care will be taken to minimize these risks. The biopsy will leave a small scar, but this will fade over time.

There may be unforeseen and unknown risks during the study, or after the study has been completed.

Research-Related Injury: There will be no cost to you for participation in this study. You will not be charged for any research procedures. In the event you become ill or injured as a result of participating in this study, necessary medical treatment will be made available at no additional cost to you. By signing this document you do not waive any of your legal rights. You will be compensated for your time commitment to the study, for travel to our lab, and parking expenses.

Confidentiality: While absolute confidentiality cannot be guaranteed, every effort will be made to ensure that the information you provide for this study is kept entirely confidential. Your name will not be attached to any information, nor mentioned in any study report, nor be made available to anyone except the research team. It is the intention of the research team to publish results of this research in scientific journals and to present the findings at related conferences and workshops, but your identity will not be revealed.

Voluntary Withdrawal: Your participation in this research is entirely voluntary. You may withdraw from this study at any time. If you decide to enter the study and to withdraw at any time in the future, there will be no penalty or loss of benefits to which you are otherwise entitled.
If you choose to enter the study and then decide to withdraw at a later time, all data collected about you during your enrolment in the study will be retained for analysis.

Who to Contact for Questions or Concerns: If you have questions concerning the study you can contact Dr. Philip Chilibeck at 966-1072, 343-6577, or 230-3849 (24 hour cell) or Jonathan Little (student researcher) at 966-1123.

If you have any questions about your rights as a research subject or concerns about this study, you should contact the Chair of the Biomedical Research Ethics Board, c/o the Office of Research Services, University of Saskatchewan at (306) 966-4053.

By signing below, I confirm the following:

- I have read this research subject information and consent form and I understand the contents of this form.
- I have had sufficient time to consider the information provided and to ask for advice if necessary.
- I have had the opportunity to ask questions and have had satisfactory responses to my questions.
- I understand that all of the information collected will be kept confidential and that the result will only be used for scientific objectives.
- I understand that my participation in this study is voluntary and that I am completely free to refuse to participate or to withdraw from this study at any time without changing in any way the quality of care that I receive. I understand that if I am a student a decision not to participate will not affect my academic evaluations.
- I understand that I am not waiving any of my legal rights as a result of signing this consent form.
- I understand that there is no guarantee that this study will provide any benefits to me (if applicable).
- I have read this form and I freely consent to participate in this study.
- I will receive a dated and signed copy of this form.
- I agree that my family physician can be contacted about my participation in this study:

_____Yes ______No

Participant's Name (printed):____________________________

Participant's Signature:_________________________ Date: ______________________

Name of Individual conducting the consent process
(printed):_________________________

Signature of Individual conducting the consent process:_________________________

Date: _______________________

A2.2. Questionnaire consent form

Research Participant Information and Consent Form

Title: Determination of the acceptability, taste, and glycemic index of a lentil-based meal.

Funding Agency: Saskatchewan Pulse Growers

Names of Researchers: Principal Investigator: Philip Chilibeck, Ph.D., College of Kinesiology, University of Saskatchewan, University of Saskatchewan, phone: 966-1072, Co-investigators: Gord Zello, College of Pharmacy and Nutrition, Christine Bennett, B.Sc. (student researcher, co-supervised by Gordon Zello and Phil Chilibeck), College of Pharmacy and Nutrition, University of Saskatchewan, phone: 966-2635, Albert Vandenberg, Ph.D., Department of Plant Sciences, University of Saskatchewan

Introduction: You are being invited to participate in a research study because we want to compare the effectiveness of consuming different meals (i.e., lentils, white bread, egg whites) on running performance that simulates a soccer game.

Before you decide, it is important for you to understand what the research involves. This consent form will tell you about the study, why the research is being done, what will happen to you during the study and the possible benefits, risks and discomforts.
If you wish to participate, you will be asked to sign this form. Your participation is entirely voluntary, so it is up to you to decide whether or not to take part in this study. If you do decide to take part in this study, you are free to withdraw at any time without giving any reasons for your decision and your refusal to participate will not affect your relationship with university instructors, your academic evaluations, or any other services at the university. Please take time to read the following information carefully and, if you choose, discuss it with your family, friends, and doctor before you decide.

Before you decide, it is important for you to understand what the research involves. This consent form will tell you about the study, why the research is being done, what will happen to you during the study and the possible benefits, risks and discomforts.
If you wish to participate, you will be asked to sign this form. Your participation is entirely voluntary, so it is up to you to decide whether or not to take part in this study. If you do decide to take part in this study, you are free to withdraw at any time without giving any reasons for your decision and your refusal to participate will not affect your relationship with university instructors, your academic evaluations, or any other services at the university. Please take time to read the following information carefully and, if you choose, discuss it with your family, friends, and doctor before you decide.

Purpose of the study: The purpose of the study is to measure the glycemic index (blood glucose response), taste, and acceptability of a lentil-based meal. We have previously shown that a lentil-based meal is beneficial for sports performance, but lentils given on their own are not very enjoyable. In this study we want to test a meal that might be more enjoyable.

Potential benefits: We hope to use this meal in the future to determine whether it is beneficial for endurance exercise performance. This benefit is not guaranteed. There is no direct benefit to you for participating in this study.

Procedures:

If you agree to be in this study the following will happen:

<u>Visit #1</u>

You will be asked to come to the lab in the morning after a 10-hour overnight fast. Before coming, please do not do any vigorous activities or consume any alcohol on the day before the test. Before you consume the test meal, we will collect a small amount of blood from your finger tip. This involves using a “lancet” (a sterile sharp tip) to “prick” your finger so we can obtain a drop of blood to determine blood sugar (glucose) levels. We will also measure your height and body weight.

Next, you will be randomly assigned to consume one of two meals. One meal contains white bread and the other meal contains a combination of lentils, honey, and Saskatoon berries. The amount of each meal that you will be asked to consume will be based on the available carbohydrate that is in each serving.

Meal A: You will be asked to consume approximately 590 g of the lentil meal. During this meal you will be asked to answer a number of questions regarding the taste and acceptability of the meal.

Meal B: approximately six slices of white bread.

You will have 15 minutes to consume the meal. We will then take a finger blood sample 15, 30, 45, 60, 90, and 120 minutes after consuming the meal.

<u>Visit #2</u>

At least 24 hours after visit number 1, you will come to the lab in the morning after a 10 hour fast to do the exact same procedure. During this visit, you will be asked to consume the alternative meal that you did not consume on the first day.

We will ask you to fill out a number of questionnaires on your attitudes and beliefs towards lentils, and on your general nutrition knowledge. These questionnaires will take about half an hour to fill out. These include questions on income, education and ethnicity because these factors are related to nutrition knowledge and consumption of lentils (i.e. lentils are popular in East Indian cuisine). All questions are optional. You do not have to answer any questions you are uncomfortable with.

Foreseeable risks, side effects or discomfort:

There may be some discomfort/pain during the drawing of blood. There is a risk of bruising and infection with the drawing of blood, but care will be taken to minimize these risks.

There may be unforeseen and unknown risks during the study, or after the study has been completed.

Research-Related Injury: There will be no cost to you for participation in this study. You will not be charged for any research procedures. In the event you become ill or injured as a result of participating in this study, necessary medical treatment will be made available at no additional cost to you. By signing this document you do not waive any of your legal rights. You will be compensated for your time commitment to the study, for travel to our lab, and parking expenses.

Confidentiality: While absolute confidentiality cannot be guaranteed, every effort will be made to ensure that the information you provide for this study is kept entirely confidential. Your name will not be attached to any information, nor mentioned in any study report, nor be made available to anyone except the research team. It is the intention of the research team to publish results of this research in scientific journals and to present the findings at related conferences and workshops, but your identity will not be revealed.

Voluntary Withdrawal: Your participation in this research is entirely voluntary. You may withdraw from this study at any time. If you decide to enter the study and to withdraw at any time in the future, there will be no penalty or loss of benefits to which you are otherwise entitled. If you withdraw from the study you may request that your information not be used in the study.

You may be withdrawn from the study by the investigator if you do not adhere to all study procedures.

Who to Contact for Questions or Concerns: If you have questions concerning the study you can contact Dr. Philip Chilibeck at 966-1072 or Christine Bennett (student researcher) at 966-2635.

If you have any questions about your rights as a research subject or concerns about this study, you should contact the Chair of the Biomedical Research Ethics Board, c/o the Office of Research Services, University of Saskatchewan at (306) 966-4053.

By signing below, I confirm the following:

- I have read this research subject information and consent form and I understand the contents of this form.
- I have had sufficient time to consider the information provided and to ask for advice if necessary.
- I have had the opportunity to ask questions and have had satisfactory responses to my questions.
- I understand that all of the information collected will be kept confidential and that the result will only be used for scientific objectives.
- I understand that my participation in this study is voluntary and that I am completely free to refuse to participate or to withdraw from this study at any time without changing in any way the quality of care that I receive. I understand that if I am a student a decision not to participate will not affect my academic evaluations.
- I understand that I am not waiving any of my legal rights as a result of signing this consent form.
- I understand that there is no guarantee that this study will provide any benefits to me.
- I have read this form and I freely consent to participate in this study.
- I will receive a dated and signed copy of this form.
- I agree that my family physician can be contacted about my participation in this study:

_____Yes ______No

Participant's Name (printed):___________________________

Participant's Signature:________________________ Date: _____________________

Name of Individual conducting the consent process (printed):________________________

Signature of Individual conducting the consent process:________________________

Date: ______________________

APPENDIX 3
ASSESSMENT TOOLS

A3.1. Digestive Symptoms Rating Scale

Part I - A**. Symptoms Rating Scale** – For each meal/soccer trial you will be asked to fill out a symptoms rating scale. Please complete it to the best of your ability.

Date:

Subject #:

Subject initials:

Experimental Condition: 1 2 3 4

For each time-point listed below, please describe how you feel for each of the symptoms listed. Use the following scale to rate your experience of the symptoms listed in the table;

0 - No Symptoms
1 - Mild Symptoms
2 – Moderate Symptoms
3 – Moderately Severe Symptoms
4 – Severe Symptoms

Time (min)	Fullness	Bloating	Nausea	Abdominal Cramping	Hunger
-140 Baseline					
-120 Post Meal					
-105 15min Post					
-90 30min Post					
-60 60 min Post					
-30 90min Post					
0 120min Post Meal					
45 Half-time					
90 Biopsy					
105 Posttime trial					

A3.2. Sensory Test Meal Analysis

– B - Test Meal Analysis

This section of the questionnaire will be used to assess the sensory qualities of the test meals, as well as your physiological symptoms after consuming the meal. Please rate the following statements.

1. How did the meal look?

Not appealing	Some what Appealing	Neutral	Appealing	Very Appealing
[ ]	[ ]	[ ]	[ ]	[ ]

Comments:

____

____

2. What did you think about the size of the meal?

Very small	Small	Average	Large	Cumbersome
[ ]	[ ]	[ ]	[ ]	[ ]

Comments:

____

____

3. How did you find the ease of consuming the entire meal? If you had difficulties consuming the entire portion can you describe why?

Not Easy	Somewhat Easy	Neutral	Easy	Very Easy
[ ]	[ ]	[ ]	[ ]	[ ]

Comments:

____

____

____

4. Did the meal have an aroma?

[ ] Yes
[ ] No [ ] I don't know
Comments:

5. Is the aroma of the meal appealing?

[ ] Yes
[ ] No

[ ] I don't know
Comments:

6. What is the texture of the meal?

Not tolerable	Somewhat Tolerable	Neutral	Tolerable	Very Tolerable
[ ]	[ ]	[ ]	[ ]	[ ]

Comments:

7. How did you find the ease of chewing and swallowing the meal?

Not Easy	Somewhat Easy	Neutral	Easy	Very Easy
[ ]	[ ]	[ ]	[ ]	[ ]

Comments:

8. The flavour of the meal was?

Not appealing	Some what Appealing	Neutral	Appealing	Very Appealing
[ ]	[ ]	[ ]	[ ]	[ ]

Comments:

____

____

____

9. Do you feel you will be able to exercise with ease at the beginning of the testing (in approximately 2 hrs)? If no, why not?

Comments:

____

____

____

Thank you for completing this portion of the questionnaire. Upon completion please return the questionnaire in the envelope provided to the examiner. Ensure all the questions have been answered to your best ability and none have been left unanswered.

A3.3. 24 hour Dietary Record Form

Name:______________________________ Date:__________________________

BREAKFAST:

SNACK:

LUNCH:

SNACK:

DINNER:

SNACK:

OTHER:

A3.4. 24 hour physical activity record form

24-hr Physical Activity Record

Name:_____________________________________

Please record all physical activity/exercise that you performed on:____________________

Activity	Duration	Details (Intensity, Sets/Reps, etc.)

A3.5. Nutritional knowledge and attitudes toward pulse-based diet questionnaire

Nutritional knowledge and attitudes towards a pulse-based diet questionnaire

University of Saskatchewan
2008

Pulses, also referred to as legumes, are seeds of plants. These include beans (kidney beans, white beans, black beans, navy beans), soy beans, chickpeas, peas (i.e. split peas), and lentils (red, yellow, and green).

Part 1:

As part of your participation in this study, we ask that you fill out this questionnaire to help us better understand your attitudes about consuming pulse-based meals. Please answer all of the questions in this section.

1. Some people believe that eating pulses (i.e. Lentils) has specific difficulties. How much, if at all, do these statements apply to you? (Please circle one answer for each of the statements)

I believe that eating pulse-based meals is difficult because:

	Strongly disagree	Disagree	Not sure	Agree	Strongly agree
I need more information about pulses	☐	☐	☐	☐	☐
I don’t want to change my eating habit or routine	☐	☐	☐	☐	☐
My family/partner wont eat a meal containing pulses	☐	☐	☐	☐	☐
Pulse-based meals or snacks are not available when I eat out	☐	☐	☐	☐	☐
I’m too busy to prepare a pulse-based meal, I need something that’s easier to consume on the run	☐	☐	☐	☐	☐
I don’t have enough willpower	☐	☐	☐	☐	☐
Someone else decides most of the foods that I eat	☐	☐	☐	☐	☐
It would be too expensive	☐	☐	☐	☐	☐
I don’t want to eat strange or unusual foods	☐	☐	☐	☐	☐
I would have to go shopping too often	☐	☐	☐	☐	☐
There’s not enough protein in them	☐	☐	☐	☐	☐
I would get indigestion, bloating, gas or flatulence	☐	☐	☐	☐	☐
It would not be filling enough	☐	☐	☐	☐	☐
There is not enough iron in them	☐	☐	☐	☐	☐
I don’t know how to prepare pulse-based meals	☐	☐	☐	☐	☐
I wouldn’t get enough energy or strength	☐	☐	☐	☐	☐
It would not be tasty enough	☐	☐	☐	☐	☐
It is inconvenient	☐	☐	☐	☐	☐
I would need to eat such a large quantity of food	☐	☐	☐	☐	☐
It takes too long to prepare a pulse-based meal	☐	☐	☐	☐	☐
Someone else prepares my meals	☐	☐	☐	☐	☐
I don’t want people to think I’m strange or a hippy	☐	☐	☐	☐	☐

2. Some people believe that eating pulses (i.e. Lentils) has specific benefits. How much, if at all, do these statements apply to you? (Please circle one answer for each of the statements)

	Strongly disagree	Disagree	Not sure	Agree	Strongly agree
I believe that pulse-based meals can help decrease my saturated fat intake	☐	☐	☐	☐	☐
I believe that pulse-based meals have lots of fibre	☐	☐	☐	☐	☐
I believe that pulse-based meals help me to improve my energy levels throughout the day	☐	☐	☐	☐	☐
I believe that pulse-based meals have lots of vitamins and minerals	☐	☐	☐	☐	☐
I believe that pulse-based meals help prevent disease in general (e.g. heart disease, diabetes)	☐	☐	☐	☐	☐
I believe that a pulse-based meals help me to improve my digestion	☐	☐	☐	☐	☐
I believe that pulse-based meals could help me to eat a greater variety of foods	☐	☐	☐	☐	☐
I believe that pulse-based meals are a good source of protein	☐	☐	☐	☐	☐
I believe that pulse-based meals could help me to stay healthy	☐	☐	☐	☐	☐
I believe that a pulse-based meals can help me to have a better quality of life	☐	☐	☐	☐	☐
I believe that a pulse-based meals can help me to control my weight	☐	☐	☐	☐	☐
I believe that a pulse-based meals can help me to be fit	☐	☐	☐	☐	☐
I believe that pulse-based meals can be a part of a tasty diet	☐	☐	☐	☐	☐
I believe that pulse-based meals can help the environment	☐	☐	☐	☐	☐
I believe that pulse-based meals can help me to save money	☐	☐	☐	☐	☐
I believe that pulse-based meals can help me to be more content with myself	☐	☐	☐	☐	☐
I believe that pulse-based meals can help me to look more ‘trendy’ to my friends	☐	☐	☐	☐	☐

PART 2 – Nutritional Knowledge

For each question, please pick the number that best describes your answer:
1 = Strongly Disagree
2 = Disagree
3 = Undecided
4 = Agree
5 = Strongly Agree

		SD	D	U	A	SA
1	An equivalent weight of carbohydrate and protein have approximately the same caloric value	1	2	3	4	5
2	Carbohydrates are not as easily and rapidly digested as protein and fat	1	2	3	4	5
3	A slice of bread is an example of 1 serving from the bread and cereals food group	1	2	3	4	5
4	Honey contains fewer calories than an equal amount of sugar	1	2	3	4	5
5	Foods such as potatoes and honey are best eaten after exercise	1	2	3	4	5
6	Eggs and legumes are examples of protein sources other than meat	1	2	3	4	5
7	Protein is the primary source of muscular energy for the athlete	1	2	3	4	5
8	Protein is not stored in the body; therefore, it needs to be consumed every day	1	2	3	4	5
9	All red meat is high in saturated fat	1	2	3	4	5
10	No more than 15% of calories in the diet should be provided by fat	1	2	3	4	5
11	Substitution of polyunsaturated fat for some saturated fat is recommended to lower the risk of heart disease	1	2	3	4	5
12	Adequate fat intake is necessary for estrogen production	1	2	3	4	5
13	Broccoli is a plant source of calcium	1	2	3	4	5
14	Milk is a good supplier of calcium of all age groups	1	2	3	4	5
15	800 milligrams of calcium per day is the recommended dietary allowance (RDA) for females aged 15-24	1	2	3	4	5
16	Adequate calcium intake is necessary for female athletes of all ages to prevent osteoporosis	1	2	3	4	5
17	Two 8-ounce glasses of milk is enough to fulfill the recommended amount of calcium per day	1	2	3	4	5
18	Carbonated beverages can negatively affect calcium metabolism	1	2	3	4	5
19	Iron-deficiency anemia results in a decrease in the amount of oxygen that can be carried in the blood	1	2	3	4	5
20	Cheese is a good source of iron in the diet	1	2	3	4	5
21	Those with a meatless diet are at a higher risk of iron deficiency	1	2	3	4	5
22	Iron in meat is absorbed at the same rate as iron in a plant food	1	2	3	4	5
23	Due to menstruation, females need more iron in their diets than men	1	2	3	4	5
24	A lack of iron in the diet can result in fatigue, injury, and illness	1	2	3	4	5
25	Meat and eggs are good sources of zinc	1	2	3	4	5
26	Bananas and avocadoes are good sources of potassium	1	2	3	4	5
27	Vitamin supplementation is recommended for all physically active people	1	2	3	4	5
28	Excess vitamin supplementation may harm the physically active person	1	2	3	4	5
29	Vitamins in mineral-enriched foods are not used by the body as well as naturally occurring vitamins	1	2	3	4	5
30	Vitamins are a good source of energy	1	2	3	4	5

31	Green, leafy, and yellow vegetables are important because they help ensure the vitamin A requirement for the individual	1	2	3	4	5
32	Carrots are a good source of vitamin A	1	2	3	4	5
33	Whole milk is a better source of vitamin D than skim or 2% milk	1	2	3	4	5
34	The body can synthesize vitamin D upon exposure to the sun	1	2	3	4	5
35	Potatoes, strawberries and cantaloupe are good sources of vitamin C	1	2	3	4	5
36	The best sources of folic acid are supplemented grain products and fortified breakfast cereals	1	2	3	4	5
37	Vitamin E is required for blood clotting	1	2	3	4	5
38	Salt is an essential part of a healthy diet	1	2	3	4	5
39	Fibre in the diet may help to decrease constipation, decrease blood cholesterol levels, and prevent cancers	1	2	3	4	5
40	Bread and cereals is the only food group that is a good source of fibre	1	2	3	4	5
41	Two servings of vegetables per day fulfills recommended dietary allowances	1	2	3	4	5
42	Dark-colored vegetables have more nutritional value than pale vegetables	1	2	3	4	5
43	Fresh, frozen, and canned vegetables all have similar nutrient values	1	2	3	4	5
44	Nutrients can be destroyed if vegetables are overcooked	1	2	3	4	5
45	Eating oatmeal may decrease the risk of heart disease	1	2	3	4	5
46	Carotenoids work to prevent the formation of free radicals	1	2	3	4	5
47	Natural and organic foods are more nutritious than foods grown under conventional methods	1	2	3	4	5
48	Dehydration can impair physical performance	1	2	3	4	5
49	During activity, thirst is an adequate guide for the need for fluids	1	2	3	4	5
50	During exercise, mass ingestion of large amounts of fluids is preferred over frequent ingestion of small amounts	1	2	3	4	5
51	An athlete should drink no water during practice, but rather rinse out his/her mouth or suck on ice cubes	1	2	3	4	5
52	Sports drinks are the best way to replace body fluids lost during exercise	1	2	3	4	5
53	Alcohol consumption can affect absorption and utilization of nutrients	1	2	3	4	5
54	Alcohol has more calories per gram than protein	1	2	3	4	5
55	Caffeine has been show to improve endurance performance	1	2	3	4	5
56	Caffeine can increase the risk of dehydration	1	2	3	4	5
57	An athlete involved in endurance events (e.g., distance running) should follow a considerably different diet than one participating in events of short duration (e.g., sprinting)	1	2	3	4	5
58	A physically fit person eating a nutritionally adequate diet can improve his/her performance by consuming greater amounts of nutrients	1	2	3	4	5
59	A muscular person expends more energy at rest than a non-muscular person of the same age, sex and weight	1	2	3	4	5
60	A 200-pound person uses about twice as many calories to run a mile as a 100-pound person	1	2	3	4	5
61	A person with a higher percentage of body fat may weigh less than a person of the same size with a greater muscle mass	1	2	3	4	5
62	A Sound nutritional practice for athletes is to eat a wide variety of different food types from day to day	1	2	3	4	5
63	Skipping meals is justifiable if you need to lose weight quickly	1	2	3	4	5
64	When trying to lose weight, acidic foods such as grapefruit are of special value because they burn fat	1	2	3	4	5

65	If trying to lose weight, carbohydrates should come only from fruits and vegetables rather than from breads and pastas	1	2	3	4	5
66	The relationship of good eating habits to good health should be stressed to the athlete	1	2	3	4	5
67	Coaches need to have good attitudes toward nutrition because of their close contact and influence upon athletes	1	2	3	4	5
68	The type of food an athlete eats affects his/her physical performance	1	2	3	4	5
69	What the athlete eats is only important if the athlete is trying to gain or lose weight	1	2	3	4	5
70	Nutrition is more important during the competitive season than during the off=-season for the athlete	1	2	3	4	5
71	Food advertisements are a very reliable source of nutritional information	1	2	3	4	5
72	It is the coach's responsibility to stress good nutritional practices	1	2	3	4	5
73	The athlete should schedule his/her activities so he/she has time to eat	1	2	3	4	5
74	Learning about nutrition is not important for athletes because the eat so much food they always get the nutrients their bodies need	1	2	3	4	5
75	Learning facts about nutrition is the best way to achieve favorable changes in food habits	1	2	3	4	5
76	Nutritional counseling would be important to the athlete who is trying to change his/her weight	1	2	3	4	5

Part 3:
Demographic Information

1. What is your gender?
   - ☐ Male
   - ☐ Female

2. What is your age? _____

3. Which of the following best describes your employment status at this time?
   - ☐ Full time employment
   - ☐ Part time employment
   - ☐ Student with full time employment
   - ☐ Student with part time employment
   - ☐ Student with part time employment during the academic year
   - ☐ Student
   - ☐ Unemployed

4. What is the highest level of education that you have completed?
   - ☐ Some high school
   - ☐ Completed high school
   - ☐ Some community college/technical institute
   - ☐ Completed community college/technical institute
   - ☐ Some university
   - ☐ Completed university (undergraduate degree)
   - ☐ Some graduate studies
   - ☐ Completed graduate degree

5. Which of the following categories best describes your household total gross annual income?
   - ☐ $0-$9,999
   - ☐ $10,000-$19,999
   - ☐ $20,000-$29,999
   - ☐ $30,000-$39,999
   - ☐ $40,000-$49,999
   - ☐ $50,000-$59,999
   - ☐ $60,000-$69,999
   - ☐ $70,000-$79,999
   - ☐ $80,000 and over

6. How many persons are living in your household (including yourself)?_______
   - ☐ What are the ages of these persons? ______________________

7. Which of the following best describes your formal nutrition training?
    - ☐ Do not have any
    - ☐ High school course
    - ☐ College and/or university course
    - ☐ Other, please state:______________________

Current Dietary practices:

8. How would you describe your dietary practices
    - ☐ Vegetarian
    - ☐ Lacto-vegetarian
    - ☐ Lacto-ovo-vegetarian
    - ☐ Vegan
    - ☐ Mixed diet (consumes foods from all four food group

9. Are your food habits influenced by your cultural or ethnic background?

    ☐ Yes   ☐ No

10. To which ethnic or cultural group(s) do you belong?

    ____
    ____
    ____

11. Are your food habits influenced by any restrictions?

    ☐ Yes   ☐ No

    If yes, please specify
    - ☐ Allergies, please specify: ____
    - ☐ Disease, please specify: ____
    - ☐ Prescribed diet, please specify: ____
    - ☐ Other, please specify: ____

12. How many times per week to you consume pulses?

    ☐ 0   ☐ 1   ☐ 2   ☐ 3   ☐ 4   ☐ 5   ☐ 6   ☐ 7

13. How many times per week to you consume lentils?

☐	☐	☐	☐	☐	☐	☐	☐
0	1	2	3	4	5	6	7

Physical Activity:

14. How many exercise sessions do you have in a week?

☐	☐	☐	☐
0-1	2-4	5-7	>7

15. What is the average duration of your exercise session?
    - ☐ 0-10 minutes
    - ☐ 11-20 minutes
    - ☐ 21-40 minutes
    - ☐ 41-60 minutes
    - ☐ 61-90 minutes
    - ☐ 91-120 minutes
    - ☐ >120 minutes

16. What is your typical pre-exercise meal: size and composition?

____

____

____

____

____

General Health:

17. Do you participate in any of these health conscious activities? Please indicate all applicable choices:
    - ☐ Nutritional label reading
    - ☐ Watching fat intake
    - ☐ Monitoring fast food meals each week
    - ☐ Monitoring candy or snack foods each week
    - ☐ Eat at least 5 servings of fruits and vegetables each day
    - ☐ Dietary supplementation with vitamins and minerals
    - ☐ Other, please specify:____

18. In general, would you say your health is:
    - ☐ Excellent
    - ☐ Very good
    - ☐ Good
    - ☐ Fair
    - ☐ Poor